# An examination of body perception and body image concerns within exercising and other at-risk populations

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April 2022

# Declaration

I declare that this thesis, ‘An examination of body perception and body image concerns within exercising and other at-risk populations’, represents my own work, except where otherwise stated. None of the work referred to in this thesis has been accepted in any previous application for a higher degree at this or any other University or institution. Quotation marks have been used to distinguish all quotations, with specific acknowledgement to the information source.

Submitted by: Jack Mitchell

Signature of Candidate: 

Date: 24/04/2022

# Acknowledgements

Throughout my PhD studies I have received a great deal of support and assistance. This PhD would not have been possible without the help and guidance of these people.

I would firstly like to thank my supervisor Dr Helge Gillmeister for all her support, patience, and kindness throughout my PhD. Your work ethic and passion are truly inspiring. Thank you for providing me the opportunity to embark on this PhD.

I also wish to express my gratitude to both the Department of Psychology and the School of Sport, Rehabilitation and Exercise Sciences at the University of Essex for their funding and support during my PhD. It has been a pleasure to work within such warm, welcoming, and inclusive environments. I would also like to thank the administrative staff for their support, especially Trudi Day and Hazel Cromer.

I would like to thank my schoolteachers Tony Winter, Sue Mitchell, and Dale McMorran, who helped me to develop a passion for learning and to discover self-belief in my academic abilities.

Finally, I wish to thank my family, for all your wise council and unconditional support. Special thank you to Mum, Dad, Rosa, and dog Jasper for your constant comfort, reassurance, and patience.

# Abstract

Exercising for weight change and appearance related reasons is associated with disordered eating, body dissatisfaction, and diminished well-being. This thesis sought to establish the association between body perception and body image concern within exercising and other at-risk populations. Initially, we investigated the cortical stages of visual body- and gender-sensitive processing, as well as body inversion effects (BIE), in observers at risk of eating disorders (ED), body dysmorphic disorder (BDD) and/or muscle dysmorphia (MD). We found some evidence to suggest a configural processing disruption of body stimuli in high-risk groups, suggesting atypical configural body representation is not only present in women at-risk of body image-related disorders, but might extend to men at-risk of MD. Gender-sensitive body processing was observed in women only.

A series of online studies were conducted to investigate the relationship between body processing and body image concerns amongst exercisers. We found increased time spent resistance training positively correlated with interoceptive awareness, maladaptive body image and supplement use. We also found during the COVID-19 pandemic that MD symptoms positively associated with increased mood disturbance, social media use, and elevated perceptions of pressure to engage in body transformative exercise. Additionally, we found in an online visuospatial body map task that performance was associated with increased body image disturbance in women, highlighting implications for understanding how configural body tasks can be used to assess body image concerns in the general population. Finally, we proposed an

online study to assess attentional biases in low- and high-risk gym-goers toward MD-relevant stimuli such as bodies, muscle-building supplements, and gym equipment.

It is concluded that processes indicative of body perception, in both brain and behaviour, present atypically in women at-risk of EDs/BDD, and differ to those in men at-risk of MD. Importantly, body-structural perception measures appear a suitable approach to delineating individuals at-risk of MD.

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# Chapter 1 General Introduction

## Motivation of thesis

As many as a third of British adults feel anxious or depressed because of their body image (Mental Health Foundation, 2019). Many societies promote and place value on physical appearance, promoting the notion that attractiveness, happiness, and success are only achieved from obtaining the idealised body (Levine, Smolak, Moodey, Shuman, & Hessen, 1994), this sort of environment affects people, and places them at-risk of developing a body image related disorder.

These pervasive concerns over body image become reinforced through the media, in particular social media, where its users are regularly bombarded with images of the ideal body (Mental Health Foundation, 2019). Unsurprisingly, extant literature has associated media exposure with both body dissatisfaction and disordered eating within female populations and more recently within male populations too (Fatt, Fardouly, & Rapee, 2019; Harrison & Cantor, 1997; Negrin, Skemp, & Baumann, 2018; Saiphoo & Vahedi, 2019). Furthermore, promotion of the body ideal has been suggested to provoke changes in society's behaviour towards both diet and exercise, which has led to the prevalence of resistance training to now be one of the most popular forms of exercise worldwide (Thompson, 2017). In addition, the popularity of dietary supplements and substances has increased, (Congeni & Miller, 2002; Froiland, Koszewski, Hingst, & Kopecky, 2004), and anabolic-androgenic steroids use in both adolescents and adults is now estimated to be at an all-time high (Calfee & Fadale, 2006; Lader 2016; Pope Jr et al., 2014).

For a long time, body image concerns have been perceived as a largely specific to females with eating disorders being much more common among females. This has led to an abundance of research examining the drive for thinness within female populations. Where research has shown that body image disturbances experienced in women with eating disorders and body dysmorphic disorders are multifaceted constructs, arising from interrelated contributions from perception, cognition, affect and behaviour (see Cash, 2004; Cash, 2012). However, not until the late 20th century there was a shift in attention toward establishing an improved understanding of body image aspects specific to males (Mishkind, Rodin, Silberstein, & Striegel-Moore, 1986; Parent, Schwartz, & Bradstreet, 2016). Males are encouraged to achieve an increasingly elusive combination of high muscularity and leanness (McCreary & Sasse, 2000). Therefore, this thesis is primarily concerned with investigating perceptual contributions to body image disturbance in men and other populations at-risk by assessing the relationship between how the observer feels about their own body (body image) and body perception.

## Body Dissatisfaction

In recent decades, society's expectations of the ideal physique for both men and women has evolved (Leit, Pope Jr, & Gray, 2001; Maier, Haeussinger, Hautzinger, Fallgatter, & Ehlis, 2017; Sypeck, Gray, & Ahrens, 2004). Over time there has been a gradual increase in popularity of the pursuit for enhanced muscles. Currently, for males, the body ideal is to be lean and muscular (Hausenblas, Brewer, & Van Raalte, 2004; Labre, 2005). For females, the body ideal was to be slim, but that is changing; presently, there is greater emphasis also for females to obtain a lean and muscular physique (Hausenblas et al., 2004; Wroblewska, 1997).

At present, it commonly accepted that a discrepancy between the individual's perceived body and their desired body, drive the pursuit to obtain the ‘perfect’ body. This body discrepancy has often been used as a visual measure of body dissatisfaction in figural rating scales (Cohen et al., 2015; Fingeret, Gleaves, & Pearson, 2004; Gardner & Brown, 2010; Gleaves et al., 2000; Talbot, Cass, & Smith, 2019). Thompson et al. (1999) proposed the tripartite influence model to explain thin idealisation in females. The tripartite influence model suggests that societal pressures to be thin come from three sources: family, peers, and the media, leading women to compare themselves to others (social comparison) and to ‘buy into’ and accept the notion that to be beautiful one must be thin (thin-ideal internalisation). This social comparison and thin-ideal internalisation encourage women to feel greater body dissatisfaction, which in turn leads them to engage in unhealthy eating behaviours directed towards attaining what they perceive to be the ideal thin body (Thompson et al., 1999). Recently, the female fit body ideal is becoming arguably more popular and has been associated with increased body dissatisfaction, disordered eating, and compulsive exercise (Donovan, Uhlmann, & Loxton, 2020).

Therefore, for men is its understandable that being aware of a discrepancy between one’s actual body and one’s ideal muscular body, is likely to reinforce the desire to obtain the ideal body. This internalisation has been found to cause a higher drive for muscularity, leading individuals to engage in behavioural change intended to aid the pursuit for the idealised muscular body shape (Hausenblas et al., 2004; Wroblewska, 1997). In attempt to achieve these muscular bodies, individuals make extreme alterations to their diet and exercise regimes (Hausenblas et al., 2004; Robert, Munroe-Chandler, & Gammage, 2009). Any deviation from these strict diet and exercise regimes results in extreme distress and anxiety (Pope Jr, Gruber, Choi, Olivardia, & Phillips, 1997). This perceived negative body image has been associated with intentional diminishment of social, occupational, or recreational activities, relentless mirror checking, and reassurance seeking behaviours, to enable both workout and diet schedule continuation. Additionally, this negative body image results in many avoiding circumstances that may expose their body, such as regularly wearing bulky clothes to conceal their own body from others (Pope Jr et al., 1997). In their desperation to diminish this body discrepancy and increase body satisfaction, individuals often resort to using steroids (Muller, Dennis, Schneider, & Joyner, 2004; Olivardia, Pope Jr, & Hudson, 2000). This pathological pursuit for the ‘perfect’ muscular body has been recently termed as muscle dysmorphia (Pope Jr et al., 1997).

# Muscle Dysmorphia

## Defining features

Muscle dysmorphia (MD) is also commonly known as ‘reverse anorexia’ or ‘bigorexia’, due its shared characteristics with anorexia nervosa. MD was first identified in male bodybuilders (Pope Jr et al., 1997), and was included in the most recent Diagnostic and Statistical Manual of Mental Disorders, 5th Edition (DSM-5) as a dysmorphic disorder subtype (American Psychiatric Association, 2013). MDs defining feature is the belief that one's body is small, insufficiently muscular and / or insufficiently lean, despite one’s body being objectively muscular in size (Grieve, 2007). Obsessive behaviours towards nutrition and exercise regime are typical of individuals with MD (Lantz, Rhea, & Cornelius, 2002; Muller et al., 2004; Murray, Rieger, Touyz, & De la Garza García, 2010; Olivardia et al., 2000; Pope Jr et al., 1997).

## Classification controversy

MD can often be comorbid with other disorders, such as eating disorders, depression, or obsessive-compulsive disorder, and therefore is often misdiagnosed and undetected (Murray et al., 2010; Pope et al., 2005). Potentially due to its complex comorbidity, at present, psychologists remain in dispute over its current classification (Blomeley, Phillipou, & Castle, 2018; dos Santos Filho, Tirico, Stefano, Touyz, & Claudino, 2016; Phillipou, Blomeley, & Castle, 2016). Since MD was included into the DSM-5 under a body dysmorphic subtype classification, it has resulted in further controversy surrounding its classification. A recent review of the muscle dysmorphic literature demonstrated that most research has proposed that MD should be reclassified into a new body image disorder category within the DSM-5, this was due to MD demonstrating unique elements (compared to BDD and AN) in its presentation and behaviours that suggest it may represent a discrete entity (Blomeley et al., 2018).

## Prevalence

The prevalence of MD is at present unknown, however, it is believed to be as common as other body image related disorders, such as anorexia and bulimia nervosa (between 0.5% and 1.0% of the population; APA, 2013). MD is most commonly observed amongst recreational gym users and bodybuilders. Research that has sampled from these at-risk populations, such as weightlifters and fitness professionals, have produced prevalence estimates to be typically ranging between 10 and 25% (Campagna & Bowsher, 2016; Diehl & Baghurst, 2016; Pope & Katz, 1994). More recently, MD has been found to have a prevalence of 2.2% among adolescent boys and 1.4% among adolescent girls (Mitchison et al., 2021). Although research relating to prevalence estimates contribute to the knowledge of MD prevalence, larger population-based studies utilizing techniques that guarantee representative samples are required. Such a study may improve understanding of MD, achieved through its contribution toward clear diagnostic criteria and psychometrically robust instruments.

MD has also been observed amongst individuals participating in sports at both recreational and elite levels (Cerea, Bottesi, Pacelli, Paoli, & Ghisi, 2018). Sports that incorporate an element of aesthetics towards evaluating performance, such as gymnastics, figure skating, synchronised swimming and diving, have been acknowledged as a risk factor toward the development of MD (Skemp, Mikat, Schenck, & Kramer, 2013). In addition to aesthetics, sports where resistance training is part of the athlete's training regime, and sports where weight restrictions are imposed, have reported an increased susceptibility in developing MD amongst (Hildebrandt, Schlundt, Langenbucher, & Chung, 2006).

Actions that can be considered as a result of body image concern, such as engaging in bodybuilding activities (e.g., weightlifting) and consequently possessing a muscular body, are also presently perceived as indicators of healthiness and/or wellness by society (SantaBarbara, Whitworth, & Ciccolo, 2017). This perception has arguably resulted in MD and other body image related disorders often being undetected or misdiagnosed (Hunt, Thienhaus, & Ellwood, 2008; Phillips, 2006). At present, the diagnostic criteria set out in the DSM-5 states that there are four clear criteria relating to MD: the individual has a preoccupation with or perceived deficits in their physical appearance; the preoccupation causes clinically significant distress or impairment in social, occupational, or other important areas of functioning; these preoccupations trigger excessive and repetitive behaviours, and finally, the primary focus is not related to body fat or weight as in an eating disorder. The MD specifier is defined as the individual having a preoccupation focused on their physique being too small or insufficiently muscular (American Psychiatric Association, 2013).

Despite the inclusion of the diagnostic criteria within the DSM-5, according to a recent systematic review, a significant body of research utilises the diagnostic criteria set out by Pope and colleagues instead (Pope Jr et al., 1997) and identified no studies that employ the DSM-5's manual criteria in their research (Sandgren & Lavallee, 2018). The lack of research employing the recent DSM-5 diagnostic criteria may be attributed to the controversy surrounding its classification. According to the DSM-5, it recommends that for individuals to be diagnosed with MD, they must meet the criteria for a body dysmorphic disorder, with a primary preoccupation related to their inadequate muscularity (American Psychiatric Association, 2013). This classification of MD as a specifier of body dysmorphic disorder has been questioned within the literature, with numerous researchers stipulating that MD may be more accurately classified as an eating / body image disorder, or even an addiction disorder (Chung, 2001; Foster, Shorter, & Griffiths, 2014; Murray, Rieger, et al., 2012). Furthermore, reviews have also stated that there is a lack of empirical support for the validity and reliability surrounding the current diagnostic criteria for MD (Blomeley et al., 2018; Nieuwoudt et al., 2016). Despite an influx of research in recent years concerning MD, research used to formulate diagnostic criteria consists solely of correlational findings. Assessing MD from a neurobiological or cognitive perspective could potentially provide a greater insight into the development and maintenance of the disorder, especially in regard to body image distortion and eating pathology within muscle dysmorphic populations (Blomeley et al., 2018).

## Risk Factors

The aetiology of MD has been conceptualised most often within a biopsychosocial framework (Grieve, 2007; Ricciardelli & McCabe, 2004). Typical biopsychosocial risk factors for MD formation have most often mimicked those evidenced from traditional eating disorders, including neuroticism, low intrinsic self-worth, perfectionism, negative affect, and internalised appearance ideals (Cafri et al., 2005; Davis, Karvinen, & McCreary, 2005; Grieve, 2007). It has also been found that individuals with MD are more likely to report a history of abuse or bullying as a child and/or an adolescent (Tod, Edwards, & Cranswick, 2016; Wolke & Sapouna, 2008). Furthermore, individuals with MD are more likely to have a history of eating pathology and concerns regarding their weight and or shape (Cafri, Blevins, & Thompson, 2006; Mosley, 2009; Pope Jr et al., 1997; Pope Jr, Katz, & Hudson, 1993), with males exhibiting muscle dysmorphic symptoms often reporting distress related to their masculinity (Murray & Griffiths, 2015; Ung, Fones, & Ang, 2000), and females with muscle dysmorphic symptoms often having a history of physical or sexual assault (Gruber & Pope Jr, 1999; Pope Jr et al., 1997).

While undoubtedly not a gender exclusive disorder, the literature suggests men are at a significantly greater risk of developing MD than are women (Blomeley et al., 2018). Resulting from this, MD research has over-represented male populations within its samples (Murray et al., 2017). This may have arisen due to muscularity being associated with the typical male body ideal and as a perceived sign of masculinity (Kimmel & Mahalik, 2004). This arguably has therefore led researchers to examine male populations to greater detail when compared to its female counterparts. Traditionally, females idealise thin bodies, with less emphasis toward a muscular body ideal (Oehlhof, Musher-Eizenman, Neufeld, & Hauser, 2009), and have therefore less commonly associated muscularity with femininity, compared to males and masculinity (Leone, Sedory, & Gray, 2005). However, in contrast to the previously suggested dominance of thinness-oriented body ideals within women, recent research has found there to be a similar prevalence for thin, lean, and muscular body ideals within female populations (Hartmann, Steenbergen, Vocks, Büsch, & Waldorf, 2018; Tiggemann & Zaccardo, 2018). There is increasing acknowledgement for a female body ideal to be muscular and lean, however despite its rise in popularity, it remains far less popular than the muscular and lean male body ideal. At present, only a few studies have reported MD to exist across sport and exercise domains in female populations (Hale, Diehl, Weaver, & Briggs, 2013; Negrin et al., 2018)

The value society has placed on physical appearance has not only been acknowledged within adult and adolescent populations, but within child populations too (Medina, Arévalo, Díaz, Hernández, & Rayón, 2012; Skemp-Arlt, Rees, Mikat, & Seebach, 2006). There has been a long-established concern regarding the association between thin Barbie dolls and body dissatisfaction among girls, which has been confirmed experimentally (Dittmar, Halliwell, & Ive, 2006; Rice, Prichard, Tiggemann, & Slater, 2016). Also, there is an abundance of research assessing body dissatisfaction within children (Birbeck & Drummond, 2006; Blissett, Lysons, & Norman, 1996). However, with boys, it was not until recently that concerns have been raised surrounding the muscularity of action figure toys and its association with body dissatisfaction (Baghurst, Griffiths, & Murray, 2018; Barlett, Harris, Smith, & Bonds-Raacke, 2005; Pope Jr, Olivardia, Gruber, & Borowiecki, 1999). Over recent decades the muscularity of action figures have become more pronounced, which can only be associated with a rise in popularity for the muscular body ideal (Pope Jr et al., 1999). Like observations made with Barbie dolls contributing to girls' pursuit for thinness, exposure to figures with extreme muscularity have been suggested as a contributing factor to the development of the pursuit for muscularity within children and young adolescents (Pope Jr et al., 1999). In addition to these claims, a study conducted with preschool children revealed that even at such an early age, boys desire to have bigger bodies (Ilker Kerkez, 2013), supporting the notion that it is possible for muscularity body ideals to be comprehended at an early age.

## Burden

Despite a lack in clarity concerning the predisposing and precipitating components of MD, more is understood in relation to the physical and psychological outcomes of those with MD. There is a significant body of research that consistently states that MD is associated with various deleterious consequences, such as greater levels of lifetime mood, anxiety or eating disorders in addition to concomitant internalising and pathological eating symptomatology (Cafri et al., 2006; Olivardia et al., 2000). Adverse health outcomes including increased likelihood of renal failure, physical injury, and sudden cardiac death have been attributed to the pathological behaviours common with individuals with MD (Cafri et al., 2005); such behaviours include exercise pathology and disordered eating, and appearance/physique enhancing drug usage. The pathological engagement in the aforementioned behaviours, such as the avoidance of social situation due to the anxiety and excessive time attributed to exercising, results in further impairment, leading to negative sequelae including the breakdown of romantic relationships, employment loss, and overall poorer quality of life (Gruber & Pope Jr, 1999; Pope Jr et al., 1997). Finally, due to the increased probability of polysubstance abuse in muscle dysmorphic populations, individuals are more susceptible to exhibit clinical aggression, mania, and/or psychosis (Hildebrandt et al., 2011; Pope Jr & Katz, 1988).

## Cultural Specificity

MD alongside other body image related disorders has been attributed to exist primarily within western societies and is assumed to be uncommon or non-existent in other societies where value in physical appearance is relatively lacking, particularly in regard to muscularity (Kanayama & Pope Jr, 2011). However, with the media, and specifically social media, becoming widely available across global communities, it means that both the muscular body ideal and MD that originates from Western cultures, may be more widespread than originally proposed (Babusa & Túry, 2012; Monocello, 2022). An example of the dispersion and growth of muscularity popularity has been observed in the sport of bodybuilding. Countries in the Middle East, Africa, and Asia, were formerly classed as placing limited value on physical appearance and especially a muscular body ideal, have been seen to adopt a growing significant interest in the sport of bodybuilding and the muscular body ideal. Many of these countries now host largely spectated national bodybuilding competitions and even have contestants represent their country in popular international elite level competitions. This is concerning as the bodybuilding population harbours the largest prevalence of MD (Lantz et al., 2002; Pickett, Lewis, & Cash, 2005), with the desire to achieve a muscular body ideal being associated with participation in this sport (Pickett et al., 2005). Therefore, MD, originally suggested as being mostly limited to Western society, may be more widespread than initially thought. There still remains much debate over the true cause(s) of MD, however it has been well established that participating in the sport of bodybuilding has a strong association with the development and maintenance of MD compared to other populations (Babusa & Túry, 2012; Cella, Iannaccone, & Cotrufo, 2012).

## Body-image Disturbance and Muscle Dysmorphia

An extant body of literature conceptualises MD as a body image disturbance (Cafri, Olivardia, & Thompson, 2008; Hildebrandt et al., 2006; Pope Jr et al., 1997; Thomas, Tod, & Lavallee, 2011), where individuals express a chronic preoccupation with inadequate muscularity. Body image is deemed as a multifaceted construct that comprises of an individual's cognitive (what we think about our bodies), affective (what we feel about our bodies), perceptual (how we perceive our bodies), and behavioural (what kind of behaviours we engage in in the case of body dissatisfaction) experience of one's body (Grogan, 2016). These aspects of body image also interact with our culture, media, social environment, and individual factors, which in turn, interact leading to a positive or negative body image (Healey, 2014). When negative cognitions and emotions become associated with an individual's body image, body perception and (dis)satisfaction begin to detrimentally affect self-worth or body esteem (Clay, Vignoles, & Dittmar, 2005; Stice, 1994), or result in clinical distress and/or dysfunctional behaviours (Barlett et al., 2005).

For a long time, body image concerns have been perceived as a largely female problem because eating disorders are much more common among females. This has led to an abundance of research examining the drive for thinness within female populations. However, the late 20$^{th}$ century saw a shift in attention toward establishing an improved understanding of body image aspects specific to males (Mishkind, Rodin, Silberstein, & Striegel-Moore, 1986; Parent, Schwartz, & Bradstreet, 2016). The body image concerns originally identified in male populations were found to be more diverse compared to females (Cafri & Thompson, 2004; Corson & Andersen, 2002). Males are encouraged to achieve an increasingly elusive combination of high muscularity and leanness, such that research examining this muscle-oriented body image concern has identified a phenomenon termed the ‘drive for muscularity’ (McCreary & Sasse, 2000). Like the drive for thinness construct, drive for muscularity has been termed as a preoccupation with one’s muscularity and behavioural attempts to increase muscle mass (McCreary & Sasse, 2000). Despite this drive not solely occurring in the presence of body image or MD disorders, it has been supported as a risk factor for the presence of MD (Robert et al., 2009). Although further research is required, a recent meta-analytic review of the drive for muscularity indicated that preliminary research supports the association between MD and the drive for muscularity (Edwards, Tod, & Molnar, 2014).

Body image distortion, a disturbance in the perception of one’s appearance, is an additional component of body image that is implicated in MD research (Rosen, 2013). Body image distortion has been conceptualised as a core symptom of MD. This suggestion is implicit in the description of MD as specifier of body dysmorphic disorder, where muscle dysmorphic behaviours are assumed to be mostly provoked by the distorted perception of muscularity (American Psychiatric Association, 2013). This distorted perception of muscularity has been also reported in Pope’s original research (Pope Jr et al., 1993) and subsequent studies (Mosley, 2009; Pope Jr et al., 1997; Ung et al., 2000). Within these studies, individuals with MD are reported to typically describe themselves as small, despite being of objective muscular build (Hernández-Martínez, González-Martí, & Jordán, 2017; Pope Jr et al., 1997; Pope Jr et al., 1993). Despite this evidence, at present, there is an absence of quantitative data examining the role of body image distortion within muscle dysmorphic populations, with an over-reliance on anecdotal reports.

Body image-related behaviours are widely acknowledged as representing a core component of MD behavioural symptomatology. Central to body dysmorphic disorder are compulsive and repetitive behaviours, such as obsessive mirror use or checking of the area of concern, attempts to conceal or fix the area, and excessive reassurance seeking regarding the area of concern (American Psychiatric Association, 2013). Although there are no body image-related behaviours described in the DSM-5 criteria that are exclusive to the MD specifier, previous proposed criteria acknowledged that individuals who have MD will attempt to hide the area of concern, within their avoidance of physique exposure criterion (Pope Jr et al., 1997). Avoidance of physique exposure behaviours were initially identified in studies by Pope and colleagues (1993, 1997), individuals were reported to avoid mirrors, wear loose and ill-fitting clothing to conceal muscularity, and avoid both public changing rooms and sexual intercourse. These findings have since been corroborated in reports from muscle dysmorphic clinical populations and case studies (Baghurst, 2012; Mosley, 2009; Murray, Maguire, Russell, & Touyz, 2012).

Despite the clinical and case study validation, there is insufficient support for physique exposure avoidance as a criterion of MD within quantitative research literature. Research has suggested the present criterion poses limited reliability and is not unique to muscle dysmorphic populations (Nieuwoudt et al., 2016). In a review of Pope's et al.'s (1997) MD criteria, Nieuwouldt et al. (2016) reported that the avoidance of physique exposure criterion demonstrated inadequate inter-rater reliability and was the least common of the criteria among the literature.

Although no other compulsive or repetitive behaviours have been defined in the DSM-5 specifier for MD or within Pope's proposed criteria (1997), both clinical case studies and empirical research within muscle dysmorphic populations have identified other body-image protection behaviours (Mosley, 2009; Murray & Griffiths, 2015; Murray, Maguire, et al., 2012).

These behaviours have included reports of both avoidance and frequent mirror checking or use of scales; attempts to enhance muscularity; and reassurance seeking from others regarding muscularity. These seemingly contradictory behaviours of frequent checking and avoidance are consistent with Fairburn's transdiagnostic model of eating disorders (Fairburn, Cooper, & Shafran, 2003). The model suggests that these activities contribute to increased investment toward self-worth and over-evaluation of weight and or shape, which therefore increases the preoccupation and emotional investment toward body image. This model has received support for its use in predicting muscle dysmorphic symptomatology (Murray, Rieger, Karlov, & Touyz, 2013), however the support for these behaviours and the model is limited and requires further investigation within clinical muscle dysmorphic populations.

## Behavioural Symptomatology

Another behaviour that has been well regarded to exist within in almost all cases of MD is extreme exercise behaviour. Exercise participation is commonly acknowledged as a benefit toward health, individuals with MD possess pathological behaviours towards exercise. Typically, individuals with MD have a rigid exercise regime that is strongly adhered to, where any deviation from their schedule results in severe anxiety (Gruber & Pope Jr, 1999; Mosley, 2009; Pope Jr et al., 1997). This obsessive behaviour toward exercise commonly results in a dysfunction in both social and occupational domains, causing clinical distress (Gruber & Pope Jr, 1999; Mosley, 2009; Pope Jr et al., 1997). Despite injury and against medical advice, individuals with MD have reported to adhere to their strict exercise regimes, as in not doing so would result in elevated levels of distress (Olivardia, 2001). Presently, the existence of an exercise symptomatology is commonly accepted as existing within muscle dysmorphic populations, however there is the opinion this may be partly exaggerated by the sampling method employed by most researchers, such as investigating weightlifting, bodybuilding, and athletic populations.

This relationship with exercise has also been suggested to result in significant preoccupation, with individuals dedicating an excessive amount of time absorbing fitness and health magazines, in addition to online content and social media, to learn new and improved techniques and strategies to advance their exercise routine (Murray, Rieger, & Touyz, 2011). It has been suggested that the content on pro-muscularity websites promote non-healthful muscularity-oriented eating and exercise practices, which are thought to contribute toward the development and maintenance of eating disorders and/or MD (Murray, Griffiths, Hazery, et al., 2016). In some instances, the maintenance of these dysfunctional exercise behaviours and their associated preoccupation has resulted in individuals departing from successful careers to become personal trainers (Gruber & Pope Jr, 1999).

The use of anabolic androgenic steroids and other appearance and performance enhancing supplements and substances originated in elite athletes, however, increasingly appearance and performance enhancing drug use has been adopted for the purpose of body modification (Millman & Ross, 2003), and to aid dietary control, exercise, and performance within the general population (Hildebrandt et al., 2011). Research has indicated that the use of appearance and performance enhancing drugs, particularly steroids, has become more normalised behaviour within bodybuilding populations (Coquet, Roussel, & Ohl, 2018). This is concerning as the pathological use of illicit appearance and performance enhancing drugs can result in adverse psychiatric and medical complications including cardiomyopathy, cancer, comorbid psychiatric symptomatology, and premature death (Kanayama & Pope Jr, 2011). Despite these pathological associations, appearance and performance enhancing drug use can result in physical and psychological outcomes which include euthymic mood, increased muscle mass, reduced adiposity, increased confidence, and improved athletic performance (Hildebrandt, Langenbucher, Carr, & Sanjuan, 2007). Specifically, by using anabolic androgenic steroids, the level of lean muscularity is considerable and beyond achievement via regular body modification practices such as diet and exercise (Rohman, 2009). This is concerning, as it is well known that a considerable proportion of men and women hold a hyper-muscular body ideal, especially within bodybuilding populations, which are unachievable without anabolic androgenic steroid use. MD was originally hypothesised as a precipitating and/or a maintaining factor in anabolic androgenic steroids use (Pope Jr et al., 1993). While it is accepted that anabolic androgenic steroids use in muscle dysmorphic population is significantly greater than in other body dysmorphic disorders and in healthy populations (González-Martí, Fernández-Bustos, Contreras Jordan, & Sokolova, 2018; Pope et al., 2005), there is still a lack of understanding of the prevalence of other appearance and performance enhancing drug use in muscle dysmorphic populations.

Recently, studies have explored in more detail the associations between muscle dysmorphic symptomology and use of appearance and performance enhancing drugs. These studies have shown a significant relationship between extent of drug use and overall muscle dysmorphic symptomology, suggesting not only that body image disturbance is most severe in long-term drug users, but also demonstrating the importance of assessing drug use with clinical cases of MD (Harris, Dunn, & Alwyn, 2019; Hildebrandt et al., 2011). There has been compelling evidence to suggest that body image disturbance is most severe within long-term appearance and performance enhancing drug users (Kanayama, Barry, Hudson, & Pope Jr, 2006), emphasising the importance of investigating appearance and performance enhancing drug use within clinical muscle dysmorphic populations.

Dietary and nutritional supplements are an alternative to illicit appearance and performance enhancing drug usage and are regarded as a more natural and safer alternative for achieving similar ergogenic benefits (Carvey, Farina, & Lieberman, 2012; Hartmann & Siegrist, 2016). It has been estimated that the prevalence of appearance and performance enhancing drugs are as high as 90% within elite athletes and approximately 40% within amateur athlete and gym-using population (Barkoukis, Lazuras, Lucidi, & Tsorbatzoudis, 2015; Burns, Schiller, Merrick, & Wolf, 2004). These licit drugs are promoted as being able to increase the user's speed, endurance, performance, and strength, as well as reducing recovery time and modifying both body shape and size (Muller, Gorrow, & Schneider, 2009). Their use is frequently undertaken without any supervision or medial guidance (Kao, Deuster, Burnett, & Stephens, 2012; Mooney et al., 2017) which is concerning given that these products often lack support for their purported benefits and can contain both illicit and harmful ingredients (Abbate et al., 2015; Kohler et al., 2010; Nissen & Sharp, 2003). As reported in illicit appearance and performance enhancing drugs, licit drugs have also be associated with deleterious physical consequences, including rhabdomyolysis, cardiac syncope and arrhythmias, seizures, hospitalisation, and premature death (Flanagan, Kaesberg, Mitchell, Ferguson, & Haigney, 2010; Nordt et al., 2012; Stahl, Borlongan, Szerlip, & Szerlip, 2006), coupled with greater levels of intention to use illicit appearance and performance enhancing drugs (Hildebrandt, Harty, & Langenbucher, 2012).

The measurement of both licit and appearance and performance enhancing drugs usage in muscle dysmorphic populations has been hindered by a lack of psychometrically supported assessment. Until only recently, there were no psychometric scales to assess appearance and performance enhancing substance and supplement use. The Appearance and Performance Enhancing Supplement/Substance APES scale is the first scale to be validated for use to assess appearance and performance enhancing drugs across large samples (Cooper, Griffiths, & Burns, 2019). Prior to this, research focused on appearance and performance enhancing drug usage assessment relied upon individual questions of unknown psychometric validity and reliability, arguably failing to capture the breadth of appearance and performance enhancing drug usage (Ntoumanis, Ng, Barkoukis, & Backhouse, 2014; Petrocelli, Oberweis, & Petrocelli, 2008; Sagoe et al., 2015).

## Eating Pathology

MD has also been commonly referred to as “reverse anorexia”, originating from its labelling of the syndrome by Pope and colleagues (Pope Jr et al., 1993). They described reverse anorexia as presenting similarly to anorexia nervosa except regarding body image disturbance and related behaviours, which are reversed. The most apparent example of contrasting symptoms is observed in the domain of eating pathology. Here, individuals with anorexia nervosa restrict their eating, using dieting methods in attempt to reduce their size/shape. Comparatively, individuals with MD, in general, use dieting methods in attempt to increase their size/shape. While the eating pathology within anorexic populations is clear, the eating pathology within muscle dysmorphic populations is presently unclear, however.

Since MD was included into the DSM-5 as a subtype of body dysmorphic disorder, there has been a conceptual shift away from the notion that dieting and eating pathology are a central component of MD (Pope Jr et al., 1997). This shift has been supported by research which has emphasised body image disturbance and disordered exercise as more prevalent within individuals with muscularity-oriented body dissatisfaction than disordered eating (Chittester & Hausenblas, 2009; Robert et al., 2009).

A significant limitation of research investigating the eating pathology amongst muscle dysmorphic populations is the use of assessment measures that focuses mainly on one category of eating pathology, the drive for thinness (Cafri & Thompson, 2004; McCreary & Sasse, 2000). Disordered eating practices for the intention of appearance modification could also include behaviours to gain weight/muscularity, however (McCreary, Hildebrandt, Heinberg, Boroughs, & Thompson, 2007). As muscle dysmorphic behaviours are triggered by the desire to increase muscularity, most thinness-oriented disordered eating measures are inconsistent with this muscularity pursuit. Arising from this, research relating to muscularity-oriented disordered eating has started to gather pace (Griffiths, Murray, & Touyz, 2013; Murray, Griffiths, & Mond, 2016). Muscularity-oriented disordered eating has been recently defined as a cluster of pathological eating attitudes and behaviours, which are motivated by the pursuit of muscularity, and which may include both eating to increase leanness in addition to muscularity (Griffiths et al., 2013). Typically, this includes increased caloric intake, bingeing, overconsumption of protein-based foods, and restriction of fats and carbohydrate-based foods (Griffiths et al., 2013; McCreary & Sasse, 2002; Murray, Griffiths, & Mond, 2016; Petrocelli et al., 2008). These behaviours have been reported in children as young as 8 years old (Eisenberg, Wall, & Neumark-Sztainer, 2012; Ricciardelli & McCabe, 2004), and are reported to be as prevalent in males as thinness-oriented dieting behaviours are in females (Cafri et al., 2005; Nowell & Ricciardelli, 2008).

Despite this concern, only up until recently, there was no established and relevant muscularity-oriented disordered eating behaviour assessment. The Eating for Muscularity Scale is the first scale devised that adequately assesses this pathological muscularity-oriented eating behaviour (Cooper et al., 2019). Previously, for research to examine muscularity-oriented disordered eating, modified versions of established eating disorder scales, pertaining to thinness-oriented disorder eating, were utilized to better reflect muscularity concern (Murray, Rieger, et al., 2012). Findings from such research support the suggestion that eating pathology could be more of an integral feature of MD than previously considered. Rates of muscularity-oriented eating behaviour were found to be similar across both anorexic and muscle dysmorphic populations, and those males with MD reported significantly higher traditional eating pathology than healthy controls. With adequate measurement, such as the eating for muscularity scale (Cooper et al., 2019), the role of eating pathology in muscle dysmorphic populations can be better assessed and ultimately understood.

## Bodybuilding and Muscle Dysmorphia

The sport of bodybuilding requires considerable investment in training and diet regimes (Spendlove et al., 2015). Competitive bodybuilding consists of various weight and physique specific categories, for men there are three main divisions: men's physique, classic physique, and bodybuilding, and for women there are four main divisions: bikini, figure, female physique, and female bodybuilding. Judges will score competitors according to balance of size, symmetry, and muscularity. The dietary intake of bodybuilders has been described as both structured and periodised (Spendlove et al., 2015), where particular attention is prescribed to energy and macronutrient targets, which are commonly adhered to during each phase of preparation towards competitions (Mitchell, Slater, Hackett, Johnson, & O'Connor, 2018). In the off-season, in general, bodybuilders will focus on increasing muscle mass, placing less regard toward body fat levels. This has been evidenced in previous research demonstrating overall energy intake in bodybuilders to be highest during the off-season, particularly regarding protein, fat, and carbohydrates (Spendlove et al., 2015). Contrastingly, during the in-season the athletes' focus changes towards reducing fat mass whilst maintaining muscle mass, and diet changes are also reported to be incorporated to achieve this fat loss. At this stage, bodybuilders report a reduction in overall energy intake, with carbohydrate and fat intake being significantly lower than off-season levels (Spendlove et al., 2015). However, protein intake remains similar to the protein intake during the off-season (Kistler, Fitschen, Ranadive, Fernhall, & Wilund, 2014; Rossow, Fukuda, Fahs, Loenneke, & Stout, 2013; Spendlove et al., 2015). Whilst in the competition preparation period, bodybuilders monitor their intake using food diaries and food scales, ensuring that their goals regarding energy and macronutrients are achieved (Kistler et al., 2014; Rossow et al., 2013). Importantly, the rate at which athletes reduced their body weight during competition preparation has been found to have the highest positive association with MD symptomatology (Mitchell et al., 2018). The post-competition phase is less structured than the in-season (Rossow et al., 2013). Immediately following competition, bodybuilders monitor their food intake less frequently and place less concern toward their energy and macronutrient targets (Walberg-Rankin, Edmonds, & Gwazdauskas, 1993). Total energy is greatly increased, and therefore body weight increases. In addition to the regimented food intake, bodybuilders exploit dietary supplements to aid the accumulation of muscle mass, improve exercise performance, and complement their usual dietary intake (Hackett, Johnson, & Chow, 2013).

Concerning bodybuilders' training regimes, at present, there is minimal research. Research suggests that exercise regimes of bodybuilders are reflective of their specific and periodised goals (Hackett et al., 2013; Kistler et al., 2014). Typically, bodybuilders follow a high-volume resistance-training schedule, with very low volumes of aerobic exercises. Bodybuilders generally split their routine into focusing on specific muscle groups for each training session. On average, four to five training session were reported to be performed per week, where each muscle group is trained once or twice per week (Hackett et al., 2013). In each training session, bodybuilders typically conduct 4-5 exercises per muscle group and will perform 7-12 repetitions at a maximum (Kistler et al., 2014). This regime targets muscle hypertrophy (an increase and growth of muscle cells). As bodybuilders move into their in-season, the training routines are adjusted to represent the goal of reducing fat mass whilst maintaining muscle mass. Small alterations are made to the resistance training regime, which include reductions in set number to 3-4 per exercise, and an increase in repetitions to 7-15 repetitions at a maximum per set. This alteration intends to maintain muscle mass despite remaining in a total energy long term deficit. At this stage, it is common for aerobic training to be increased significantly to aid fat loss. The frequency of aerobic exercises varies across the in-season, over five seasons per week have been reported (Hackett et al., 2013; Kistler et al., 2014). In addition to both resistance and aerobic training, during the in-season preparations bodybuilders also commence posing practice (Robinson, Lambeth-Mansell, Gillibrand, Smith-Ryan, & Bannock, 2015). This involves holding isometric contractions of the major muscle groups for 30-60 seconds while the limbs and torso are in a position intended to make the muscles appear large and defined (Rossow et al., 2013).

Due to the extreme dietary and exercise regimes of bodybuilding, various psychological disorders have been associated with the sport, such as eating disorders (Bratland-Sanda & Sundgot-Borgen, 2013; Goldfield, 2009; Goldfield, Blouin, & Woodside, 2006), exercise addiction (Hurst, Hale, Smith, & Collins, 2000), and most notably MD (Mosley, 2009). There are similarities in the meticulous approach bodybuilders and individuals with MD have towards physique development. Because of the overlapping approach in physique development, it is logical to consider that the sport of bodybuilding and the context may appeal to those exhibiting muscle dysmorphic symptoms. Greater muscle dysmorphic symptoms have been reported in bodybuilders in comparison to power lifters (Lantz et al., 2002), fitness lifters (Hale et al., 2013), non-training individuals (Bernadett Babusa, Urbán, Czeglédi, & Túry, 2012; Santarnecchi & Dèttore, 2012), and college football players (Baghurst & Lirgg, 2009). Despite this, at present, it remains unclear whether bodybuilding contributes to the manifestation of MD, or if the sport of bodybuilding attracts those predisposed to, or already exhibiting symptoms of, MD (Mitchell et al., 2018).

## Treatment of Muscle Dysmorphia

Consistent with the lack of researching pertaining to the development and maintenance of MD, the treatment of the disorder has seen little research. At present, there have been no interventions developed with the specific purpose of preventing or treating MD. Without such interventions, it has been proposed that MD be treated with treatments used for body dysmorphic disorder, obsessive-compulsive disorder and/or eating disorders. Several case studies have demonstrated effective results for the use of pharmacological interventions (Phillips, O'Sullivan, & Pope Jr, 1997; Ung et al., 2000), cognitive therapy (Ung et al., 2000; Outar, Turner, Wood, & O'Connor, 2021), and family-based therapy (Murray & Griffiths, 2015). The effectiveness of these treatments is likely to be enhanced through utilising a combination of established interventions. Additional recommendations have included motivational interviewing and drug therapies, such as antidepressants (Olivardia, 2007; Grieve et al., 2009). Additionally, recommended treatments have included psychoeducation, behavioural strategies to minimise both reassurance seeking and mirror checking behaviours, mindfulness to promote current body shape acceptance, and living a life of value despite perceived inadequacies (Grieve et al., 2009).

Nevertheless, these proposed treatments have not been subjected to efficacy testing within clinical trial populations.

Another promising avenue for treatment of MD may consist of approaches to treating body image disturbance in other body image disorders. This includes the utilisation virtual reality techniques and body ownership illusions discussed above, which have been shown to be successful for reducing body image distortions in anorexia nervosa (for reviews see Magrini et al., 2022; Turbyne et al., 2021), and repetitive transcranial magnetic stimulation (rTMS) (Bainbridge & Brown, 2014) of the parietal cortex, which is underactive in anorexia nervosa (e.g., Esposito, Cieri, di Giannantonio, & Tartaro, 2018; Vocks et al., 2010). A number of superior and inferior parietal cortical regions support multisensory representations of the body and rTMS has been found to aid restoration of an accurate body-image with anorexic populations (Arns, Drinkenburg, Fitzgerald, & Kenemans, 2012). As similar body-representational deficits may be observed in muscle dysmorphic individuals, these techniques potentially offer an effective means to restore an accurate body image for individuals with MD.

There is an obvious need to establish efficacious treatments for MD, which are developed specifically for individuals with MD. For this to be achieved, it is imperative to have a clear clinical understanding of MD. This acquired knowledge, will enable both appropriate targeted treatments and accurate classification of MD to be formulated, proving further support toward the extrapolation of existing protocols to muscle dysmorphic populations.

The main purpose of the research presented in this thesis is to investigate the extent body image disturbance is present in MD, which will contribute to our understanding of the potential development and maintenance of the disorder. This will be achieved through the assessing body image disturbance within individuals expressing elevated levels of muscle dysmorphic symptomatology.

## Methodological Approaches for Measuring Body Image Disturbance

An abundance of extant literature has assessed body image distortion within anorexic populations, particularly women (Cash & Deagle III, 1997; Garner, Garfinkel, Stancer, & Moldofsky, 1976). This research has commonly employed the use of figural rating scales that range in body size/shape to assess anorexic individuals' perceived body sizes and levels of body dissatisfaction, determined through the discrepancy between the perceived actual body and their body ideal (Fingeret et al., 2004). In addition to these visual assessments, other psychometric scales have been established to assess this body image pathology within anorexic populations, such as body size estimations (Skrzypek, Wehmeier, & Remschmidt, 2001).

Research into body image and its impact within sport and exercise populations is rarely assessed. Literature that has examined sport and exercise participation and its impact on negative body image, mostly focuses on body ideals and weight concerns within athletic populations (Davis et al., 2005; Morano, Colella, & Capranica, 2011; Robinson & Lewis, 2016). For instance, body dissatisfaction has been found to be prevalent within male swimmers and American footballers (Steinfeldt, Gilchrist, Halterman, Gomory, & Steinfeldt, 2011; Urdapilleta, Aspavlo, Masse, & Docteur, 2010). In a pictorial body image distortion task, male swimmers were found to have more discrepancy between their perceived body and their ideal body than female swimmers, demonstrating a drive for muscularity (Urdapilleta et al., 2010). Despite MD not being assessed, future research may look to determine the prevalence of MD within swimmers, especially within males that report a muscularity body ideal. For American footballers, a strong drive for muscularity was observed (Steinfeldt et al., 2011). This was reported to be mainly attributed to the associated benefits of increasing muscularity for improved athletic ability, alongside their desire to adhere to societies' muscular body idea. This is concerning because, despite the footballers desiring to increase muscularity for the purpose of athletic ability, having muscularity as a perception or measure of athletic ability or athletic potential, may, and has been suggested to, increase the susceptibility to disordered body image ideals and MD (Galli, Petrie, & Chatterton, 2017).

Most recently, body image has been more accurately explored using self-avatars created from three-dimensional body scanners and then body size estimation was determined in a virtual reality condition (Mölbert et al., 2018; Thaler et al., 2018; Park 2018). Mölbert and colleagues (2018) found body size estimation within anorexic populations to be similar to that of healthy controls. They concluded that it might be the two-dimensional figure rating approach in assessing body size estimation that has led science to conclude anorexic populations are inaccurate in body size estimation when compared to healthy controls. However, a more recent study shows that anorexic patients overestimated their body size regardless of the assessment tool (Fisher, Abdullah, Charvin, Da Fonseca, & Bat-Pitault, 2021). More research that employs this novel technique is required to fully understand the role body image distortion has in the maintenance and development of body image related disorders, especially MD.

Similarly, feelings of body ownership have been extensively explored within anorexic and body dysmorphic disordered populations (Kaplan, Enticott, Hohwy, Castle, & Rossell, 2014; Keizer, Smeets, Postma, van Elburg, & Dijkerman, 2014). Various illusion tasks have been developed to assess ownership, such as the rubber hand illusion (Botvinick & Cohen, 1998), full body illusion (Blanke & Metzinger, 2009), size weight illusion (Case, Wilson, & Ramachandran, 2012), and body swapping (Petkova & Ehrsson, 2008). To establish a greater sense of ecological validity, these protocols have also been assessed most recently using virtual reality (Slater, Pérez Marcos, Ehrsson, & Sanchez-Vives, 2009), where they also promise to be a useful assessment and therapeutic tool for body image distortions (for reviews see e.g., Magrini et al., 2022; Turbyne et al., 2021). Research suggests that in general both individuals with eating disorders and individuals with an unhealthy body image development are more susceptible to these illusions, reporting a greater sense of ownership comparative to healthy controls (Mussap & Salton, 2006). This greater sense of ownership implies that individuals with body image disorders have a less robust ownership of their own body compared to healthy controls, implying that their own body perception is malleable compared to healthy controls (Mussap & Salton, 2006). Most recently, the full body illusion has been effectively used to improve body image disturbance within anorexic populations (Keizer, van Elburg, Helms, & Dijkerman, 2016; see also Magrini et al. 2022, and Turbyne et al., 2021, for recent reviews). More understanding surrounding body ownership as a measure and as body illusion as an intervention is required within body dysmorphic populations, particularly muscle dysmorphic populations. For example, they may be used to investigate the separate contributions of perceptual (distortions of body size) and cognitive-emotional components (negative attitudes towards the self-including body dissatisfaction) of body image disturbance. This approach has led to some recent proposals that cognitive-emotional rather than perceptual disturbances underpin anorexia nervosa (Provenzano et al., 2019; see also Neyret et al., 2020). It remains to be seen whether a similar outcome may be true for MD.

Another approach for assessing body image disturbance within body image related disorders at a cognitive level has been achieved through measuring attentional bias. Research focusing on attentional biases toward images of bodies has successfully been observed within anorexic populations when compared to health controls (Blechert, Ansorge, & Tuschen-Caffier, 2010; Fassino et al., 2002; Harrison, Tchanturia, & Treasure, 2010). Findings from eye tracking research on attentional bias have demonstrated that anorexic individuals show an attentional bias in their visual scanning behaviour toward images of bodies (both thin and fat), rather than images of social interactions, while healthy controls showed no differences in attention toward images of bodies or social images (Pinhas et al., 2014). This has been a recent topic of investigation in men where previous studies have demonstrated an attentional bias towards idealised bodies over other types of body sizes in men with high body dissatisfaction (Cordes et al., 2016; Cordes et al., 2017), men at-risk of MD (Jin et al., 2018; Waldorf et al., 2019), and appears to be a promising avenue for research into MD.

Neurobiological research conducted within anorexia and bulimia nervosa and body dysmorphic disordered populations has not yet been extended to muscle dysmorphic populations. A recent study compared the brain’s response to faces across anorexic, body dysmorphic and healthy control populations (Li et al., 2015). From electroencephalogram assessment, they found there to be similarities in the brain activity within individuals with anorexia nervosa and body dysmorphic disorders in comparison to healthy controls. They concluded, due to this similarity in event-related potentials in individuals with body dysmorphic disorder present similar deficits in areas of the brain when processing faces much like anorexic populations, suggesting perceptual distortions may contribute to poor insight toward body dysmorphic disorder. Furthermore, Li et al., (2015) found that individuals with anorexia nervosa exhibited abnormally early visual system activity, found to be consistent with reduced configural processing and enhanced detailed processing. This relationship is yet to be explored for processing bodies and within muscle dysmorphic populations.

Several behavioural studies in anorexia and body dysmorphic disorder suggest imbalances in global (configural and/or holistic) and feature-based (detailed) visual processing, although the results are not entirely consistent. Several of these studies have tested the ‘inversion effect’, which is the phenomenon that recognition of inverted faces (or other naturalistic stimuli) is normally slower and less accurate in comparison to upright faces or bodies, due to the absence of a holistic template for inverted faces or bodies. One study found reduced face inversion effects in individuals with body dysmorphic disorder compared to controls for long but not short duration stimuli, indicating a greater propensity for detailed and disjointed processing of faces, whether upright or inverted, if given enough time to study the face (Feusner et al., 2010). Another study concluded that individuals with body dysmorphic disorder had superior recognition of inverted famous faces relative to controls; this reduced inversion effect may also be an indication of greater focus on single facial features (Jefferies, Laws, & Fineberg, 2012). A study using inverted faces, scenes, and bodies found that individuals with high degree of body dysmorphic concerns also had reduced inversion effects (Mundy & Sadusky, 2014). Concerning the inversion effect within anorexia nervosa, several studies (although not all) investigating body processing in anorexia nervosa have found enhanced feature-based (detail) processing at the expense of visuospatial processing that is more global and integrated (Lopez, Tchanturia, Stahl, & Treasure, 2008; Urgesi et al., 2014). As body image has been acknowledged as a defining characteristic of individuals with MD, research concerning the feature-based and configural visual processing mechanisms in these populations are required. In addition to understanding the similarities and differences between MD and other body image disorders, such research could also provide clarity surrounding the development and maintenance of the disorder.

## Multidimensional Approach to Body Image Disturbance

Body image is conceptualised as a subjective mental schema of an individual's body appearance, attractiveness, physical health, and functioning (Cash, 2004). It is a multidimensional construct that encompasses perceptual (e.g., distortion in the visual perception of the body), attitudinal (e.g., dissatisfaction with the body) and behavioural components (e.g., body checking and avoidance; Hrabosky et al., 2009). In the broader field of body image research, great attention has been paid to the multidimensional nature of body image, which involves cognitions, behaviours, and emotions about the entire body and its functioning (Cash, 2012). Body image distortion is the central disturbance of both MD and other EDs. Presently, it is unclear whether such disturbance is the result of psychological and sociocultural factors or also reflects a biological vulnerability with involvement of brain circuits (Grieve, 2007; Kaye et al., 2009). Body image distortion can be considered as a multidimensional symptom (Cash and Deagle, 1997). However, there is not a precise and shared model of its construct and, accordingly, there are not specific assessment tools which clearly assess the different components (Banfield and McCabe, 2002). This highlights the complexity of the cognitive, perceptive, and neurophysiological components underlying the body image distortion in MD and EDs.

Comparative studies of EDs, BDD and MD that incorporate diverse aspects of body image disturbance are rare but crucial, as they might improve our understanding of all disorders and foster the longitudinal studies that will inform etiological models. In addition, further knowledge about the relationship between the disorders might help to identify research gaps with regard to studies including transdiagnostic approaches. For example, if EDs, BDD and MD occupy the unique intersection of crosscutting domains of psychopathology (e.g., a combination of deficits in perception and understanding of the self and systems for social processes) and habit perseveration (e.g., positive valence systems), they may have similar causes and therefore similar therapeutic targets. Recently, individuals with BDD and AN have been found to display significant impairments in global processing tasks compared to healthy controls (Groves, Kennett, & Gillmeister, 2020). Interesting, global processing deficits are also associated with other conditions such as obsessive-compulsive disorder (Otto, 1992) and schizophrenia (Otto, 1992; Tibber et al., 2015), which raises the question of this processing style as a potential transdiagnostic feature of mental health disorders more broadly.

Transdiagnostic approaches have been proposed specifically for EDs (Fairburn et al., 2003), with Fairburn's treatment concept (Fairburn, 2008) being successfully evaluated in a transdiagnostic treatment trial (Fairburn et al., 2009). For the much larger group of emotional disorders, several research groups have put forward the case for a transdiagnostic treatment of anxiety and depressive disorders (for an overview: Clark, 2009), and several preliminary studies investigating the Unified Protocol Treatment of Emotional Disorders in various age groups have yielded first confirmations of its efficacy (e.g., Bilek and Ehrenreich-May, 2012, Bullis et al., 2014, Chamberlain and Norton, 2013, Wilamowska et al., 2010). Therefore, examining similarities and differences across EDs, BDD and MD is warranted in order to ascertain their relatedness and develop transdiagnostic treatment approaches that could be tested in the future.

We here discuss our multidimensional model, which conceptualises the body image distortion in EDs, BDD and MD as consisting of three main components: perceptive, cognitive, and neurophysiological.

## Perceptive components

In recent years, a substantial body of research has identified the neural correlates of visual body perception has localised the visual processing of human bodies to the extrastriate body area (EBA), a bilateral region of the lateral occipital cortex where images of human bodies are responded to selectively (Downing, Jiang, Shuman, & Kanwisher, 2001; (Downing & Peelen, 2016)). Since then, research has shown that there is also evidence indicating that the extrastriate body area (EBA) contains networks that use part-based and shape information to discriminate between own body recognition and other body recognition (Chan, Peelen, & Downing, 2004; De Bellis et al., 2016; Frassinetti et al., 2008, 2011, 2012; Ferri, Frassinetti, Costantini, & Gallese, 2011; Myers & Sowden, 2008; Saxe, Jamal, & Powell, 2005). Anorectic patients overestimate their own body size more when images are presented to their left rather than their right hemisphere using a divided visual field technique (Smeets & Kosslyn, 2001). Suchan et al., (2010) reported reductions in EBA grey matter volume in the left (but not right) hemisphere of anorectic patients. Left-hemispheric abnormalities in eating disordered women may reflect atypical local, feature-based processing, especially as the left hemisphere is more generally associated with feature-based than global visual processing and selection (Fink, Halligan, Marshall, Frith, Frackowiak, & Dolan, 1996). This may relate to anorectic patients' excessive attention to detailed bodily features at the expense of configural body processing (Lang et al., 2014; Lopez et al., 2008; Urgesi et al., 2012, 2014). This imbalance in feature-based global processing also applies to the visual perception of bodies and is thought to contribute to the abnormal, detail-specific fixation on appearance related stimuli seen in disorders marked by body image disturbance (Beilharz, Atkins, Duncum, & Mundy, 2016). In particular, the processing imbalance may invoke the over-attention that those with BDD and MD pay to their own imagined or exaggerated flaws (Buhlmann, & Wilhelm, 2004; Veale, 2004; Pope Jr et al., 1997), demonstrating a need for further examination.

## Cognitive components

Recent studies employing measures of biases in attention, memory, judgment, and response suggest that body size distortion in EDs may result from cognitive bias (Williamson, 1996; Smeets, Ingleby, Hoek, & Panhuysen, 1999; Gardner, & Bokenkamp, 1996). In the context of body image, we constantly receive top-down (i.e., prior knowledge, memory, expectation about those aspects of our body) and bottom-up (info from sensory organs that can inform us about our body's shape, weight, and size) information that builds up a mental representation of our own bodies. Research has attempted to understand the underlying cognitive mechanism of this mental representation in terms of body representation and body image (Brooks, et al 2020; Caggiano, & Cocchini, 2020; Fuentes, Longo & Haggard, 2013). There is ample evidence to suggest that individuals with EDs are not able to optimally integrate incoming visual and proprioceptive/tactile/kinaesthetic information to update a current ‘online’ body percept (e.g., Keizer et al., 2011; Zucker et al., 2013) and may therefore be relying upon a stored and distorted body representation (Favaro et al., 2012). IN relation to this, cognitive theories of body dissatisfaction suggest that schemas related to appearance, shape, and weight influence the processing of information about body image (Cash & Labarge, 1996; Williamson, White, York-

Crowe, & Stewart, 2004). Where an overconcern with body size/shape can result in a body self-schema that is readily activated by external and internal cues. This self-schema is presumed to direct the person's attention to body- and food-related stimuli and to bias interpretations of self-relevant events (Williamson et al., 2004). Therefore, body image schemas may be accompanied by a number of biases that can guide selective attention to, or processing of, body image information in the environment. Which suggests that cognitive biases may play an important etiological role in the development and maintenance of body dissatisfaction and associated body image related disorders (Cash & Labarge, 1996, Williamson et al., 2004).

## Neurophysiological components

The brain's body representation is based on continuously updating multisensory signals and crucially depends on successful integration of these multiple inputs (Ehrsson, 2012; De Vignemont, 2011; Knoblich, 2002; Tsakiris et al., 2010). Moreover, it has been argued that this multisensory body representation is a fundamental mechanism for enabling conscious bodily experience and related aspects of self-consciousness (Blanke, 2012; Blanke, Slater, & Serino, 2015). Although cognitive neuroscience has traditionally focused on exteroceptive multisensory signals when investigating neural body representations (De Vignemont, 2011; Knoblich, 2002; Tsakiris et al., 2010), recent research has highlighted the importance of other sensory bodily signals, namely those coming from the inside of the body (i.e. visceral interoceptive signals) (Blanke et al., 2015; Craig, 2009; Critchley and Harrison, 2013; Damasio and Carvalho, 20130.

Extensive research has demonstrated deficits in interoception across disordered eating types and interoceptive modalities, suggesting that interoception may constitute a transdiagnostic feature of disordered eating (Dourish, Rotshtein, Spetter, & Higgs, 2019; Jenkinson, Taylor, &

Laws, 2018; Vervaet, Puttevils, Hoekstra, Fried, & Vanderhasselt, 2021; for a review, see Martin et al., 2019). Deficits in interoception, observed as alterations of inner body perception, may be considered a crucial feature of EDs. Similar to research into interoception across ED populations, there is an increasing number of studies which support the theory that lower levels of interoceptive accuracy and interoceptive awareness contribute to body-image concerns (for a review, see Badoud & Tsakiris, 2017). Yet, despite the cited evidence in interoception deficits across disordered eating populations, this has been poorly explored and compared in populations at-risk of BD and MD. Research is therefore warranted to determine whether interoception may also constitute a transdiagnostic feature of body image disturbance in populations at-risk of BD and MD.

# Rationale for the Current Thesis

## Thesis aims

Body image disturbance, such as that experienced in EDs, BDD and MD is a multi-sensory distortion to the conscious experience of the body (see Cash, 2004, 2012; Pope Jr et al., 1997). The causes of such distortions remain unclear, however, as they are underpinned and sustained by a multifaceted network of interconnected contributions from perception, cognition, affect and behaviour (e.g., De Vignemont, 2010; Feusner, Neziroglu, Wilhelm, Mancusi, & Bohon, 2010; Grogan, 2006; Stormer & Thompson, 1996; Striegel-Moore & Bulik, 2007). Nevertheless, an increasing amount of evidence indicates that the perceptual aspects of body image disturbance (e.g., fixations on perceived defects) might be related to maladapted visual processing mechanisms (see Lang, Lopez, Stahl, Tchanturia, & Treasure, 2014; Madsen et al., 2013;

Suchan, Vocks, & Waldorf, 2015, for reviews). The primary aim of this thesis was to investigate the perceptual and cognitive correlates of body image disturbance, which contributes to the development and maintenance of MD and disordered eating towards muscle-oriented foods in exercising and other at-risk populations. Ultimately, the intention was to assess the extent body image disturbance can be associated with potential electroencephalographic and behavioural markers of body-related processing in exercisers and other at-risk populations. The value of this work lies in its potential for early diagnosis of those at risk of body image disturbance, given that severe psychological distress and reduced psychosocial functioning are common symptoms of MD, EDs and BDD (Olivardia, 2001, 2007; Harris & Barraclough, 1997). Thus, a series of studies were designed to achieve the following specific aims of each study:

1. Examine early visual and later emotional stages of body- and gender-sensitive processing in observers at risk of ED, BDD and/or MD, in order to test whether the potential biomarkers of ED and BDD symptoms extend to MD, or whether MD symptomatology is associated with a unique set of behavioural and brain correlates.

2. Examine the relationship between interoceptive sensibility and the muscularity-oriented disordered eating among resistance-training exercisers, and to explore the mediating role of muscle dysmorphia symptomology and appearance and performance enhancing supplement usage in this association.

3. Examine the effect of gym closures on MD populations and the exercise community on their exercise behaviour.

4.Investigate whether distorted body-configural representations measured by an online visuospatial body map task may be an indicator of body image concern.

5. Examine whether attention allocation processes differ between gym-goers with high and low risk of MD using transient changes of bodies, supplements, gym-equipment, and neutral picture elements

## Specific Hypothesis

1. Early visual analysis of human bodies and later emotional processing would differ between ‘high-risk’ and ‘low-risk’ individuals, as reflected in event related potential responses. We also expect to observe larger event related potential responses for same-gender bodies especially or only in the high-risk groups. We also expect to observe larger event related potential responses for desirable bodies than less desirable bodies, especially for high-risk groups.

2. Lower levels of subjective interoceptive sensibility would predict heightened muscularity-oriented disordered eating. We also expect that muscle dysmorphia symptomology and appearance and performance enhancing supplement usage would mediate the relationship between interoception and muscularity-oriented disordered eating.

3. MD symptoms in gym members would be associated with frequency of social media use, increased mood disturbance, greater perceptions of pressure to exercise and to ‘transform’ their body during the lockdown. We also expect that a decrease in exercise from before to during lockdown will be associated with increased mood disturbance in those at-risk of MD compared to gym members less at risk.

4. Increased levels of body image concern (ED, BDD, MD) would predict increased task performance, over-estimation of body width on the visuospatial body map task. We also expected

that body image concern would not predict estimation accuracy of body length on the visuospatial body map task.

5. Changes to images of bodies, muscle building supplements, and gym equipment would be detected quicker on-object than off-object changes in participants with High risk MD symptomology in comparison to participants with Low risk MD.

## Overview of Thesis

The remainder of this thesis describes four empirical studies and one proposed study. In Chapter 2, we present an EEG study with two experiments, which investigated the early and later cortical processing stages of visual body- and gender-sensitive processing in observers at risk of ED, BDD and/or MD, in order to identify potential biomarkers of MD symptoms. We used a passive viewing task (Experiment 1), in which male and female bodies were merely observed but were not task-relevant, and a body discrimination task with upright and inverted male and female bodies (Experiment 2), for which body-structural processing was relevant, these were designed to test more directly whether disturbed configural and emotional processing of appearance-related stimuli can precede the onset of illnesses symptomatic of body image disturbance. To this end, we compared appearance-related configural (body-sensitive N170 ERP component and behavioural inversion effects) and emotional (late positive potential or LPP ERP component) processing mechanisms between high-risk and low-risk male and female individuals. We further correlated the obtained behavioural and brain markers of body processing to self-report measures of body image and related symptomatology. We replicate gender-sensitive N170 differences in High risk women first shown by Groves et al. (2017) and also demonstrate such effects at LPP for all female participants during the passive viewing of bodies. No such effects were observed in men. We also show altered configural processing in High risk men and women in brain (N170 inversion effects) and behaviour (inversion effects in RTs and accuracy), although these were not always in hypothesised directions. Both gender-sensitive and inversion effects not only differed between participant genders and risk groups, but they were also systematically associated with self-report measures of body image disturbance and other risk-related symptomatologies. Findings are discussed with regard to using body-sensitive and emotion-related ERPs and behavioural inversion effects as biomarkers for identifying persons at risk of developing body image disorders including MD. In Chapter 3, an online questionnaire-based study of resistance-training gym users, we show for the first time that increased muscle dysmorphic symptomology is positively correlated with higher interoceptive awareness, maladaptive body image, muscularity-oriented eating, and supplement use. Increased time spent resistance training positively correlated with interoceptive awareness, maladaptive body image and supplement use. Findings are discussed in terms of using heightened interoceptive awareness as a potential biomarker for identifying persons at risk of developing disordered eating towards muscle-oriented foods.

Chapter 4 discusses an online questionnaire-based study, which examined the effect of gym closures on the exercise behaviour in the UK gym members at-risk of MD and in the wider exercise community during the COVID-19 pandemic, and whether a change in exercise behaviour was associated with mood disturbance, increased social media use, and perceived pressures to exercise and ‘transform’ one’s body during the lockdown amongst these populations. Results indicated that increased MD symptoms predicted increased mood disturbance due to not being able exercise as normal, and these effects were enhanced for those with less access to home gym equipment and reduced perceptions of support from social media. Furthermore, results suggested that change in time spent exercising from pre-lockdown to during the lockdown predicted the severity of mood disturbance due to not being able to exercise as normal. We also showed that the reduction in time spent exercising during lockdown was significantly greater in gym members than non-gym members, as well as in those with limited home equipment (≤ 1 piece of equipment) compared to exercisers with access to more home equipment (≥ 2 pieces of equipment). This suggest that, despite gym closures being necessary to contain virus transmission, these closures may have contributed significantly towards an increase in mood disturbance, body dissatisfaction, and body image related disorders in those that exercise (particularly gym-members).

In Chapter 5, we present an online experimental study that investigated whether distorted body-configural representations (as measured by a visuospatial body map task) could be used as an indicator or diagnostic tool for heightened body image concerns. Using a novel online visuospatial body map task in a large sample of healthy participants, we sought to consider how individual differences in body image concern and body (including muscle) dysmorphic traits are related to task performance. We found that that increased body image disturbance was associated with increased speed in visuospatial body map choice task performance, in female participants only. At the same, and for female participants only, we also found that increased body image disturbance on the body dysmorphia spectrum specifically was also associated with reduced task accuracy. In line with this, we found that greater dysmorphic concern was also related with an overestimation of upper body width (but not lower body width or height) in women. In contrast, we found that measures of body image disturbance in our male sample did not relate to any aspect of performance in the visuospatial body map task. This study has implications for understanding the extent body representation can be used to assess body image concerns in the general population.

In Chapter 6, we discuss an online change blindness experimental study to investigate attentional bias in gym-goers towards muscular bodies, gym equipment, and supplements. Body-oriented attentional biases are suggested to be important cognitive-emotional factors in maintaining eating disorders and MD. Attentional bias should differ between High and Low risk groups as well as systematically relate to survey scores of body image disturbance and associated symptomatologies. We expect to find that gym-goers with enhanced body image concerns will show stronger attentional bias toward disorder-relevant stimuli, and therefore show superior change detection performance, in comparison to gym-goers with lesser body image concerns. This would suggest that, like in ED populations (Cho & Lee, 2012; Gao et al., 2011; Joseph et al., 2016; Williamson et al., 2004), cognitive biases play a key role in the development and maintenance of MD and muscle-oriented disordered eating. Which could provide a strong rationale for the application of attentional bias modification training and body exposure procedures in clinical interventions which aim to modify body dissatisfaction.

Chapter 7 contains the general discussion, where findings are summarised, followed by a discussion of what they contribute to our understanding of (persons at risk of) MD, its perceptual, cognitive, emotional, and neural correlates. We will return to a discussion of risk factors for the development and maintenance of this disorder, and end with a view toward and recommendations for future research in this domain.

Each of the four empirical chapters has been written to serve as an autonomous scientific article. As a result, there will be some overlap of the discussed literature between chapters, as well as between chapters and the general introduction/discussion. At this moment, all empirical chapters are in preparation for submission to other leading journals. Chapter 6 has been written as a proposed study because the work could not be completed in time due to Covid-19 related time and financial constraints.

# Chapter 2 Altered configural body processing in individuals at-risk of disorders characterised by body image disturbance

## Abstract

Two event related potential (ERP) studies were conducted to investigate the relationship between body image and electrophysiological signatures of body perception, with the aim of identifying potential biomarkers of body image disturbances. Occipito-parietal (P1 and N1), fronto-central (vertex positive potential), and centro-parietal (late positive potential) processing of body and non-body stimuli were assessed in 70 participants (35 male: 19 High risk muscle dysmorphia, 16 Low risk muscle dysmorphia; 34 female: 22 High risk eating disorder, 12 Low risk eating disorder).

Study 1 assessed visual processing mechanisms associated with body processing during an oddball detection task, which contained stimuli of desirable and undesirable bodies as well as infrequent images of animals that required a response. We found that High risk eating disorder women showed gender-sensitive N170 ERP effects for more desirable bodies, which may reflect upward social comparisons, which was source localised to right occipitotemporal cortex. In contrast, Low risk eating disorder women only showed such gender-sensitive effects at later processing stages (late positive potential). We found a positive correlation of the N170 gender effect with Eating Disorder Inventory-3 personal alienation in women. No convincing N170 or

late positive potential gender-sensitive effects were seen in male participants, nor did any such effects systematically relate to male body image.

In study 2, participants indicated whether successively presented upright or inverted male and female bodies, which were shown from different viewpoints (front and back), were of the same or different identity. Typical N170 body inversion effects were seen in the low-risk groups, whilst there was some evidence to suggest a disruption to the configural processing of body stimuli in high-risk groups. Body inversion effects were statistically absent for female bodies in High risk men, and for male bodies in High risk women, suggesting atypical configural body representation is not only present in women at-risk of or recovering from body image related disorders, but that it might extend to men at-risk of muscle dysmorphia. These findings have implications for future research looking to inform early interventions and treatment, suggesting that populations at-risk of developing body image disorders possess atypical configural body processing.

# Introduction

Visual perception generally involves a balance between global and feature-based processing. Global processing refers to perceiving the ‘whole’ stimulus and is characterised by mental ‘exemplars’ of commonly encountered stimuli, which aid in recognition (Minnebusch, & Daum, 2009). It has been suggested that, as compared to healthy individuals (Navon, 1977), those with body image related disorders (e.g., Eating Disorder (ED), Body Dysmorphic Disorder (BDD) and Muscle Dysmorphia (MD)) potentially have a disordered imbalance between feature-based and global processing, in which they overuse feature-based processing whilst lacking in global perspective (Kollei, Schieber, de Zwaan, Svitak, & Martin, 2013; Lang et al., 2021; Li et al., 2015; Pope Jr, Gruber, Choi, Olivardia, & Phillips, 1997; Veale, 2004). The Navon task (Navon, 1977) assesses feature-based and global processing independently of one another and thus has the advantage of being able to disentangle these distinct but related components of visual perception (Blumberg, Allen, & Byrne, 2014; Caparos, Linnell, Bremner, de Fockert, & Davidoff, 2013). Research using the Navon task has demonstrated feature-based and global visual processing differences in ED populations (e.g., Becker et al., 2017; Shepherd, Ladis, Jiang, & He, 2021). In other research, the Embedded Figures Test (a tasks that requires feature-based processing) has demonstrated that women with AN have superior task performance compared to healthy women (Lopez, et al., 2008; for review, see Lang, Lopez, Stahl, Tchanturia, & Treasure, 2014). Furthermore, during a local-global figures task, women who reported greater (subclinical) ED symptoms showed increased feature-based processing as indexed by early visual ERPs (P1 and P3) (Moynihan et al., 2016).

This imbalance in feature-based global processing also applies to the visual perception of bodies and is thought to contribute to the abnormal, detail-specific fixation on appearance related stimuli seen in disorders marked by body image disturbance (Beilharz, Atkins, Duncum, & Mundy, 2016). In particular, the processing imbalance may invoke the over-attention that those with BDD and MD pay to their own imagined or exaggerated flaws (Buhlmann, & Wilhelm, 2004; Veale, 2004; Pope Jr et al., 1997). Concerns with appearance, beyond body size and shape, are a common feature of EDs (Kollei et al., 2013), with high comorbidity between EDs, BDD, and MD (Dingemans, van Rood, de Groot, and van Furth, 2012; Devrim, Bilgic, & Hongu, 2018). One of the earliest links between MD and EDs was described by Pope et al., (1997), in which 22% of male participants with characteristics of MD also formerly met diagnostic criteria for Anorexia Nervosa, after replacing the earlier preoccupation with being too fat with being too small. Since then, MD has been included in the Diagnostic and Statistical Manual of Mental Disorders Fifth Edition (DSM-5: American Psychological Association, 2013) as a subtype of BDD, while EDs are classified separately to BDD despite the overlap in body image disturbance.

In recent years, a substantial body of research has identified the neural correlates of visual body perception (Downing & Peelen, 2016) and shown some abnormalities within those correlates in those with body image disorders. Research has localised the visual processing of human bodies to the extrastriate body area (EBA), a bilateral region of the lateral occipital cortex where images of human bodies are responded to selectively (Downing, Jiang, Shuman, & Kanwisher, 2001). Since then, research has shown that this area is primarily concerned with processing body parts and possibly the shape of the body (Downing & Peelen, 2016). Furthermore, there is also evidence indicating that EBA contains networks that use part-based and shape information to discriminate between own body recognition and other body recognition (Chan, Peelen, & Downing, 2004; De Bellis et al., 2016; Frassinetti et al., 2008, 2011, 2012; Ferri, Frassinetti, Costantini, & Gallese, 2011; Myers & Sowden, 2008; Saxe, Jamal, & Powell, 2005). Anorectic patients overestimate their own body size more when images are presented to their left rather than their right hemisphere using a divided visual field technique (Smeets & Kosslyn, 2001). Suchan et al., (2010) reported reductions in EBA grey matter volume in the left (but not right) hemisphere of anorectic patients. Left-hemispheric abnormalities in eating disordered women may reflect atypical local, feature-based processing, especially as the left hemisphere is more generally associated with feature-based than global visual processing and selection (Fink, Halligan, Marshall, Frith, Frackowiak, & Dolan, 1996). This may relate to anorectic patients' excessive attention to detailed bodily features at the expense of configural body processing (Lang et al., 2014; Lopez et al., 2008; Urgesi et al., 2012, 2014).

However, the same research group (Suchan et al., 2013) later showed that what is reduced in anorexia is in fact the connectivity between EBA and fusiform body area (FBA), with greater reductions linked to greater body size misjudgements. Interestingly, such reductions were also specific to the left hemisphere. Less connectivity between EBA and FBA was interpreted as an imbalance between feature-based and configural processing. As EBA responds to body parts as well as whole bodies (e.g. Downing et al., 2001; Taylor, Wiggett, & Downing, 2007; Taylor, Roberts, Downing, & Thierry, 2010), it is argued to reflect feature-based rather than configural perceptual analysis (e.g. Calvo-Merino, Urgesi, Orgs, Aglioti, & Haggard, 2010; Costantini, Urgesi, Galati, Romani, & Aglioti, 2011; Downing et al., 2001; Hodzic, Kaas, Muckli, Stirn, & Singer, 2009; Taylor, et al., 2007; 2010; Urgesi, Calvo-Merino, Haggard, & Aglioti, 2007), while FBA is thought to support configural body representation (e.g. Bauser & Suchan, 2015; Peelen & Downing, 2005; Schwarzlose, Baker, & Kanwisher, 2005; Taylor et al., 2007, 2010; Urgesi et al., 2007, 2014). In line with this, Madsen, Bohon, & Feusner's (2013) review also suggested that both configural and feature-based aspects of visual processing are abnormal in anorectic and body dysmorphic patients.

Activity of the EBA has also been associated with elevated electrophysiological (EEG) activity in occipito-temporal sites around 150-190 ms after stimulus onset in response to viewing body stimuli (Pourtois, Peelen, Spinelli, Seeck, & Vuilleumier, 2007; Thierry et al., 2006). The present study investigated N170 (sometimes referred to as N190 or N1), the visual event-related component concomitant to this enhanced EEG activity (for a review see Peelen & Downing, 2007). We will refer to this component as the body-sensitive N170 throughout the present chapter. The same body-sensitive N170 component is affected by body-structural distortion (Gliga & Dehaene-Lambertz, 2005) and in women at risk of body image disturbance (Groves et al., 2017) during the passive viewing of bodies.

The body-sensitive N170 responses are altered when body stimuli are inverted, suggesting that upright human bodies are processed holistically and encoded in a configural manner (Bosbach, Knoblich, Reed, Cole, & Prinz, 2006; Minnebusch, Keune, Suchan, & Daum, 2010; Minnebusch, Suchan, & Daum, 2008; Stekelenburg & de Gelder, 2004). Body inversion paradigms reveal a negative potential peak about 170 ms after stimulus onset at posterior occipito-temporal electrodes. Stekelenburg and de Gelder (2004), for example, found that images of inverted bodies elicited a larger and delayed N170 at posterior occipito-temporal sites compared to upright bodies, whereas this differentiation between the N170 amplitude for inverted (vs. upright) objects did not emerge. Research has shown reduced recognition performance for inverted bodies compared to upright bodies, whereas this pattern is not observed for objects (e.g., Reed, Stone, Bozova, & Tanaka, 2003; Yovel, Pelc, & Lubetsky, 2010). This body inversion effect occurs because inversion disrupts the processing of configural information, and configural information is usually more important for the processing of bodies (and faces) than for objects. In addition to behavioural evidence supporting this view, researchers have investigated the time course of visual processing of bodies with respect to configural (vs. feature-based) processing. The imbalance of global vs. feature-based processing in those with high body image concern (BIC) and/or BDD has been commonly examined via stimulus inversion effects. There are also other tasks that disturb the configural processing of the body as a whole, like misalignment of halves and of limbs (e.g., Hu, Baragchizadeh, & O'Toole, 2020; Reed, Stone, Grubb, & McGoldrick, 2006; Tao, Zeng, & Sun, 2014).

This present study will use an inversion task as an index of configural body processing. An inversion task involves a task in which an initially upright image is rotated 180° from its typical orientation to become inverted (Freire, Lee, & Symons, 2000). Whilst the inversion effect (slower and less accurate processing when stimuli becomes inverted) is prominent in healthy individuals (Freire, Lee, & Symons, 2000), studies have shown that it is weaker or non-existent for those with high BIC. This represents a perceptual deviation in these individuals. For example, research focusing on the inversion effect for faces, bodies and scenes has found individuals with high BIC are able to discriminate inverted stimuli faster (faces and bodies) and more accurately (bodies and scenes) than those with low BIC (Mundy, & Sadusky, 2014; Groves, Kennett, & Gillmeister, 2020). This weakened inversion effect has been shown to increase simultaneously with BIC, such that, those with greater body dissatisfaction show superior visual processing of inverted stimuli (Beilharz, Atkins, Duncum, & Mundy, 2016). These studies (Mundy, & Sadusky, 2014; Beilharz, Atkins, Duncum, & Mundy, 2016; Groves, Kennett, & Gillmeister, 2020) identified those with varying levels of BIC in a healthy population using body dysmorphic concern psychometric measures and abnormalities through diminished inversion effects. This has also been extended to clinical populations of those diagnosed with ED (Urgesi et al., 2014), and BDD (Jefferies, Laws, & Fineberg, 2012; Feusner, et al., 2010) as well as those recovered from ED (Groves, Kennett, & Gillmeister, 2020). Interestingly, the N170 body-sensitivity has been found to be modulated by the gender of the body observed. For example, larger body-sensitive N170 amplitudes have been found to female bodies in comparison to male bodies in both men (Hietanen & Nummenmaa, 2011) and women (Alho, Salminen, Sams, Hietanen, & Nummenmaa, 2015). Women with a history of EDs or BDDs also showed a gender-sensitive response to other women's bodies over N170, while those without such a history do not show this response (Groves, et al., 2017). Both body-sensitive and gender-sensitive inversion effects have yet to be examined in those either ‘at-risk’ or clinically diagnosed with MD.

Body-sensitive N170 responses are complemented by similar ones at the vertex positive potential (VPP), where reports have described a body-sensitive enhancement of the VPP, evident over fronto-central sites, when participants view bodies in comparison to non-body stimuli (e.g., Sadeh et al., 2011; Stekelenburg & de Gelder, 2004; Van Heijnsbergen, Meeren, Grèzes, & de Gelder, 2007). Studies on the selective processing of faces suggest that VPP responses are generated by the same neural sources as N170 responses and thus reflect the same process (Joyce & Rossion, 2005). Research has found that bodies adopting a fearful posture produced an increase in the VPP (Borhani et al., 2015; Stekelenburg & De Gelder, 2004; Van Heijnsbergen et al., 2007). Furthermore, research has showed that amplitude and latency of early visual components and their associated body-sensitivity were stable over the 4-week period (Groves, Kennett, & Gillmeister, 2018). Their findings suggested that visual P1, N170 and VPP responses, alongside body-sensitive N170/VPP effects, are robust indications of neuronal activity, and that these components can be considered as electrophysiological biomarkers relevant to body-structural representations.

Another ERP component that may be relevant to disturbances in body processing is the late positive potential (LPP), which is also observed as centro-parietal positivity beginning at about 300 ms post-stimulus and overlapping initially with the P3b (for about 300–500 ms). The LPP is a sustained and continuing up to several seconds and can be observed even after stimulus offset (Cuthbert et al., 2000, Hajcak and Olvet, 2008). The LPP is thought to reflect sustained attentive processing as well as cognitive evaluation of stimulus meaning (e.g., Foti, Hajcak, & Dien, 2009; Hajcak, MacNamara, & Olvet, 2010; Schupp et al., 2006; Weinberg, Hilgard, Bartholow, & Hajcak, 2012). The LPP is enhanced to attended, task-relevant and to emotional stimuli (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Ferrari, Codispoti, Cardinale, & Bradley, 2008; Foti, Hajcak, & Dien, 2009; Gu, Mai, & Luo, 2013; Schupp, Junghöfer, Weike, & Hamm, 2003; Schupp, & Kirmse, 2021). LPP amplifications have also been reported during body processing but with somewhat mixed results regarding connections with preoccupation-related constructs (Horndasch, Heinrich, Kratz, & Moll, 2012; Mai et al., 2015). Research amongst AN patients has found that LLP amplitudes were highest when looking at pictures of underweight compared to normal-weight and overweight women, suggesting that LPP may not only code emotional valence of stimuli, but also that enhanced LPP amplitudes reflect the motivational salience of underweight figures in AN (Horndasch et al., 2012; Horndasch, et al., 2018). Furthermore, women with a heightened preoccupation have demonstrated amplified LPP responses to modified self-images, where LPP amplification was faster, stronger, and longer lasting for enlarged self-images (Uusberg, Peet, Uusberg, & Akkermann, 2018). The LPP has also been shown to reflect processing of aesthetic evaluation processes (Amodio, Bartholow, & Ito, 2014; Cui, Cheng, Lin, Lin, & Mo, 2019; Roye, Höfel, & Jacobsen, 2008; for review see Jacobsen, 2013). For example, Cui et al., (2019) showed that larger LPP were elicited in conditions with unattractive faces compared with to conditions with attractive faces. Similarly, appetitive food stimuli enhance late positivities at frontal sites relative to neutral stimuli (Gable & Harmon-Jones, 2013).

Other components that may be of interest for research on body representations, but that were not targeted in this study, include the P1, P2 and N250. The P1 is a positive waveform that peaks at occipital sites 80–120 ms after stimulus onset and is related to initial automatic processing. The P1 component has found to be enhanced when attention is directed towards a certain stimulus location and has been shown to be generated in extrastriate visual areas (Clark and Hillyard, 1996, Di Russo, Martínez, Sereno, Pitzalis, & Hillyard, 2002; Hillyard and Anllo-Vento, 1998). Meeren, van Heijnsbergen, & de Gelder (2005) ERP study found that incongruent compared to congruent body-face pairings evoked an enhanced P1 at occipital electrodes, suggesting that emotional incongruence between body and face affected the earliest stages of visual processing. Meeren et al. (2005) also found that brain processes reflected in the N170 at electrodes over posterior temporal regions were not modulated by congruency between faces and bodies. The P2 is a positive posterior deflection peaking at 200–250 ms (Zhu et al., 2015). As an early attention-related potential, it indexes fast and automatic detection of salient (emotional) stimuli (Carretié, Mercado, Tapia, & Hinojosa, 2001; Sarlo & Munafò, 2010, Zhu et al., 2015). The P2 component has been found to capture bottom-up attention in a variety of tasks, including face stimuli (e.g., see Carretié et al., 2013; Carretié, Hinojosa, Martín-Loeches, Mercado, & Tapia, 2004; Kanske, Plitschka, & Kotz, 2011; Holmes, Kiss, & Eimer, 2006; for a review see Schweinberger & Neumann, 2016). The N250 is a negative waveform over temporo-occipital sites occurring around 250 ms after stimulus onset. It is associated with the decoding of complex facial features, including those relevant to emotions (Balconi and Pozzoli, 2009, Schindler, Bruchmann, Bublatzky, & Straube, 2019; Wynn, Lee, Horan, & Green, 2008). As such, it is a marker of higher-order facial processing, including affect recognition (Güntekin et al., 2019, Olofsson, Nordin, Sequeira, & Polich, 2008).

Taken together, this body of research suggests that successive ERP components from the P1 to the LPP are sensitive to body processing and may reveal perceptual differences related to high preoccupation with body image. Despite research clearly showing that it is possible to establish links between both ED and BDD symptomatology and ERP responses (e.g., Groves et al., 2017; Li et al., 2015; Mai et al., 2015; Sfärlea et al., 2016), no ERP study to-date has investigated the temporal dynamics of body-sensitive and gender-sensitive processing in MD populations. Like with ED and BDD populations, MD has been associated with increased risk of mortality (Heywood, 1997; Petersson et al., 2006; Smith et al., 2013), making this worthy of investigation. Whether these visual processing discrepancies exist for those with MD, or in others on the BIC spectrum, that do not have clinical levels of dysmorphic concern, has received little attention (Duncum et al., 2016). It is important to understand the nature of visual body perception including feature-based perceptual and cognitive-emotional biases, their electrophysiological correlates and whether they may exist in the wider population as a marker of BIC.

The aim of the present study therefore, was to investigate the early visual and later emotional stages of body- and gender-sensitive processing in observers at risk of ED, BDD and/or MD, in order to test whether the potential biomarkers of ED and BDD symptoms extend to MD, or whether MD symptomatology is associated with a unique set of behavioural and brain correlates. Both Experiment 1 and 2 were designed to test more directly whether disturbed configural processing of appearance-related stimuli can precede the onset of illnesses symptomatic of body image disturbance. To this end, we compared appearance-related configural processing mechanisms between high-risk and low-risk individuals. The Muscle Dysmorphic Disorder Inventory (MDDI: Hildebrandt, Langenbucher, & Schlundt, 2004) and Sociocultural Attitudes Towards Appearance Questionnaire-4-Revised-Male (SATAQ-4R-Male) (Schaefer, Harriger, Heinberg, Soderberg, & Kevin Thompson, 2017) were administered to measure body image disturbances and MD symptomology in men. For women, the Eating Disorder Inventory-III (EDI-3) (Garner, 2004 Garner, 2004) and the Body Image Concern Inventory (BICI) (Littleton, Axsom, and Pury, 2005) were administered to measure body image disturbances and

ED and BDD symptomatology. For women, ‘high risk’ was determined based on a history of ED/BDD (previous diagnosis of EDs/BDD; now recovered). For men, ‘high risk’ was determined by a median split based on self-reported scores on the MDDI (Hildebrandt, Langenbucher, & Schlundt, 2004).

In Experiment 1, body-sensitive N170/VPP responses were sought over occipito-parietal electrodes, and body-sensitive LPP responses were sought over centro-parietal regions. Both N170 and VPP are widely considered body sensitivity components and are known to be generated by the same neural sources (Stekelenburg & de Gelder 2004; Joyce & Rossion, 2005) and evidenced within populations at-risk of body image disorders (Groves, Kennett, & Gillmeister, 2020). LPP enhancement has previously been demonstrated in women with enhanced BIC and has been associated with both emotional valence and motivational salience of stimuli (Horndasch, et al., 2012, 2018). Therefore, the LPP may be considered a potentially important component in populations at-risk of body image disorders. In our participant sample, it may thus signify a motivated attentional narrowing toward bodies. Experiment 1 compared the brain’s response to bodies and non-body stimuli (houses) in an oddball detection task (response required to animal pictures). The experimental design chosen was similar to Van Heijnsbergen, Meeren, Grezes, & De Gelder (2007) and Groves et al., (2017). To assess for any gender-sensitive effects over N170/VPP or LPP, images of male and female bodies were presented, which were categorised as either more desirable or less desirable bodies. Gender-sensitive effects have so far only been shown in women, but not in men (Groves et al., 2017). We predicted that the early visual analysis of human bodies and later emotional processing would differ between ‘high-risk’ and ‘low-risk’ individuals, as reflected in N170/VPP and LPP responses. We expect to observe larger N170/VPP and LPP responses for same-gender bodies especially or only in the high-risk groups (similar to Groves et al., 2017). We also expect to observe larger N170/VPP and LPP responses for desirable bodies than less desirable bodies, especially for high-risk groups (Gable & Harmon-Jones, 2013; Horndasch et al., 2012; Horndasch, et al., 2018; Uusberg et al., 2018).

For Experiment 2, body-sensitive N170/VPP responses were sought over occipito-parietal and vertex sites during a body recognition paradigm with upright and inverted male and female bodies (based on method in Groves, Kennett, & Gillmeister, 2020). For variety, bodies were shown from the front and the back (similar to what has been proposed for face-sensitive mechanisms; Caharel et al., 2009). Consistent with the perceptual literature, we expected to observe inversion effects reflected in reduced performance in inverted compared to upright trials for bodies (Groves, Kennett, & Gillmeister, 2020; Minnebusch, Keune, Suchan, & Daum, 2010; Reed, Stone, Bozova, & Tanaka, 2003; Reed, Stone, Grubb, & McGoldrick, 2006). Furthermore, we expected that 'high-risk' individuals would show reduced configural processing for bodies, indexed by smaller behavioural differences in response times and accuracy between inverted and upright body stimuli (Groves, Kennett, & Gillmeister, 2020). We also expected smaller ERP differences at N170/VPP in response to upright vs. inverted bodies. It has been hypothesised that those with disorders characterised by high body image concern might not process appearance-related body stimuli in the typical global-configural manner, but analytically, on the basis of their local features (Beilharz et al., 2016; Duncum et al., 2016; Feusner, Moller, et al., 2010; Mundy & Sadusky, 2014; Urgesi et al., 2014; Urgesi et al., 2012). If this is true also for individuals at risk of MD, we would expect that our male 'high-risk' participant group would behave similarly to our female 'high-risk' group, showing reduced body inversion effects. In addition, we expected reduced body inversion effects in high-risk vs. low risk individuals to correlate with BIC scores, such that those with higher BIC show smaller body inversion effects in both RTs and N170/VPP ERPs.

# Methods

## Participants

ERP studies investigating the body inversion effect mostly rely on within-subject designs of approximately 12–18 participants (18, 17, and 12 for Bauser & Suchan, 2013; Minnebusch et al., 2009; Stekelenburg & de Gelder, 2004, respectively), predominantly due to the cost and the duration of experiments (approximately 3 hrs). We aimed to test a minimum of 12 participants and a maximum of 20 per group. 70 participants (35 male, 35 female) from North East Essex, UK, and the surrounding area, were recruited via email advertisements to University of Essex mailing lists, as well as posters placed on notice boards at the University of Essex and local gyms.

For male participants, participants had to have been regularly using weights as part of their exercise regime for at least the last six months prior to participation. This was to ensure that weight training was an established aspect of their regular gym routine. We chose not to recruit men who had a medical diagnosis or a history of mental illness, to ensure the two groups differed as little as possible in terms of mental health. A median split of the scores on the MDDI (Hildebrandt, Langenbucher, & Schlundt, 2004) determined a male's assignment to either the high-risk MD group (n = 19) or the low-risk MD group (n = 16). Nine participants scored >39 on the MDDI which is the proposed cut-off score for 'high-risk' of MD (Varangis, Folberth, Hildebrandt, & Langenbucher, 2012).

Female participants who reported previously having an ED and/or BDD, but were no longer receiving treatment for these conditions and were weight-restored, were combined into one high-risk group (n=12) (similar to Groves et al., 2020). Weight-restored ED and BDD participants, who were no longer in treatment for these conditions, were recruited so that any differences found in questionnaire scores, behavioural data, and ERPs between the ED and control groups were not due to the effects of malnourishment (Groves, Kennett, & Gillmeister, 2017). Evidence suggests that EDs and BDD may be related variants of a body image disorder (see Cororve & Gleaves, 2001, for a review). Furthermore, the phenotypic similarities between EDs and BDD extend to psychological traits such as low self-esteem and perfectionism (Hartmann et al., 2014), which are measured by the EDI-3. The participants who reported no history of an ED or BDD (n=22) made up the female low-risk group. Those who had experienced a psychiatric illness, were not permitted to participate. One participant in the high-risk group felt unwell during the EEG testing phase and was unable to complete the computer-based tasks, and their data were subsequently removed.

Information regarding age, height, weight, waist, Body Mass Index (BMI), and hours of weekly exercise are reported in Table 1. No high-risk ED participants were underweight as defined by their Body Mass Index (BMI). Six participants reported having been previously diagnosed with anorexia nervosa only; one participant reported having been diagnosed at different times with anorexia nervosa, atypical anorexia, and eating disorder not otherwise specified (EDNOS); one participant reported a previous diagnosis of bulimia nervosa and anorexia nervosa; and two participant reported a diagnosis of bulimia alone, and one participant chose not specific which ED. Participants had been diagnosed with an ED or BDD between 1995 and 2018. Five participants self-reported as recovered from their ED or BDD, two as mostly recovered, and five as partially recovered.

Table 1 Mean (SD) demographic and biometric information for Low risk MD, High risk MD, Low risk ED and High risk ED.

| | Low risk MD (n=16) | High risk MD (n=19) | Group Comparison (T-test) | Low risk ED (n=22) | High risk ED (n=12) | Group Comparison (T-test) |
|---|---|---|---|---|---|---|
| Age (years) | 24.00 (9.64) | 27.37 (10.58) | *t* (33) = 0.98, *p* = .336 | 23.36 (3.40) | 29.42 (14.34) | *t* (32) = 1.90, *p* = .067 |
| Biometrics | | | | | | |
| Height (m) | 1.73 (0.08) | 1.76 (0.85) | *t* (33) = 0.96, *p* = .343 | 1.60 (0.86) | 1.61 (0.50) | *t* (32) = 0.27, *p* = .789 |
| Weight (kg) | 77.09 (13.72) | 80.58 (11.97) | *t* (33) = 0.80, *p* = .428 | 67.35 (16.60) | 63.16 (9.65) | *t* (32) = 0.80, *p* = .429 |
| Waist (cm) | 85.76 (10.81) | 84.14 (9.03) | *t* (33) = 0.48, *p* = .632 | 80.41 (10.53) | 73.75 (13.28) | *t* (32) = 1.61, *p* = .118 |
| BMI (kg/$m^2$) | 25.53 (3.07) | 25.98 (3.27) | *t* (33) = 0.41, *p* = .684 | 26.17 (5.69) | 24.37 (3.65) | *t* (32) = 0.99, *p* = .330 |
| Weekly exercise (hrs) | 8.48 (8.27) | 10.09 (4.67) | *t* (33) = 0.72, *p* = .124 | 4.16 (4.54) | 6.76 (4.70) | *t* (32) = 1.58, *p* = .125 |

Demographic differences between groups

Independent samples t-tests were conducted to assess how demographic information and questionnaire scores differed between high and low risk MD groups, and between high and low risk ED groups. T-tests are reported, unsigned, in Table 1. It can be seen that there were no significant differences on all measures, although the higher risk groups reported greater weekly exercise engagement compared to low risk groups. In addition, as expected, high risk ED had lower weight, waist measurements, and BMI, compared to low risk ED group.

## Ethical Declaration

The study was approved by the local Ethics Committee for the Psychology Department at the University of Essex (Ethics ID: JM1901) and endorsed by the Body Dysmorphic Disorder charity BDD Foundation, whose advice was sought during the design phase. In addition, a similar selection of stimuli had previously been approved by Beat charity for use with ED populations (see Groves et al., 2017).

## Apparatus and Stimuli

### Questionnaire Measures

Questionnaire measures differed between male and female participants. All participants except the final 7 participants (2 high risk ED women, 3 high risk MD men, and 2 low risk MD men) completed these questionnaires as part of their lab visit. The final 7 participants completed the questionnaires online before attending the lab session to minimise lab time to comply with new COVID-19 rules.

### Male Questionnaire Measures

### Muscle Dysmorphia Disorder Inventory (MDDI)

The Muscle Dysmorphia Disorder Inventory (MDDI) (Hildebrandt, Langenbucher, & Schlundt, 2004) is a 13-item measure of MD symptomatology, in which items are rated on a 5-point Likert scale, ranging from “never” (1) to “always” (5). The MDDI comprises of three subscales: Drive for Size, which consists of questions concerning thoughts of being smaller, less muscular, and weaker than desired, or wishes to increase size and strength (e.g., “I think my body is too small"); Appearance Intolerance, which consists of questions regarding negative beliefs about one's body and resulting appearance anxiety or body exposure avoidance (e.g., "I wear loose clothing so that people cannot see my body"); and Functional Impairment, which consists of questions designed to address the impairment associated with the symptoms of MD (e.g., "I feel anxious when I miss one or more workout days"). All three subscales are designed to correspond to the proposed diagnostic criteria (Pope Jr, Gruber, Choi, Olivardia, & Phillips, 1997) and yield good reliability (Cronbach's α =.77–.85; test–retest reliability *r* =.81–.87) and construct validity (Hildebrandt et al., 2004). In the present study, the Cronbach's α was .76 for the total MDDI, .82 for the Drive for Size subscale, .74 for the Appearance Impairment subscale, and .77 for the Functional Impairment subscale. Total scores range from 13 to 65, with higher scores reflecting greater MD psychopathology. A threshold value of > 39 points was proposed (Varangis, Folberth, Hildebrandt, & Langenbucher, 2012) and has been used in a previous studies on MD to identify participants at risk of MD (Lechner, Gill, Drees, Hamady, & Ludy, 2019; Longobardi, Prino, Fabris, & Settanni, 2017; Zeeck et al., 2018). The questionnaire is not a diagnostic tool but has been extensively used to identify individuals exhibiting symptoms associated with MD (Klimek, Murray, Brown, Gonzales IV, & Blashill, 2018; Pope Jr et al., 1997; Santarnecchi & Dèttore, 2012; Zeeck et al., 2018).

**Sociocultural Attitudes Towards Appearance Questionnaire-4-Revised-Male (SATAQ-4R-Male)**

The Sociocultural Attitudes Towards Appearance Questionnaire-4-Revised-Male (SATAQ-4R-Male) (Schaefer, Harriger, Heinberg, Soderberg, & Kevin Thompson, 2017) is a measure of internalisation of appearance ideals relevant to men, as well as appearance pressures emanating from peers, family, and the media. The SATAQ-4R-Male is 28-item scale, in which items are rated on a 5-point Likert scale, ranging from “Definitely Disagree” (1) to “Definitely Agree” (5). The SATAQ-4R-Male consists of seven subscales: Internalisation: Thin/Low Body Fat (e.g., “I think a lot about looking thin.”); Internalisation: Muscular (e.g., “It is important for me to look muscular”); Internalisation: General Attractiveness; Pressures: Family (e.g., I feel pressure from family members to improve my appearance”); Pressures: Peers (e.g., “I feel pressure from my peers to look in better shape”); Pressures: Significant Other (e.g., “I feel pressure from my significant other to look in better shape”); Pressures: Media (e.g., I feel pressure from the media to increase the size or definition of my muscles”). Items on each subscale are summed to produce a total subscale score ranging from 2 to 30, with higher scores indicating greater internalisation of the particular ideal. The SATAQ-4R-Male has good reliability and internal consistency (Cronbach’s α = .75) (Schaefer et al., 2017). In the present study, In the present study, the Cronbach’s α was .93 for the SATAQ-4R-Male total, .69 for the Thin/Low Body Fat subscale, .88 for the Muscular Internalisation subscale, .85 for the General Attractiveness subscale, .86 for the Family subscale, .90 for the Peers subscale, .93 for the Significant Other subscale, and .96 for the Media subscale.

**Exercise Dependency Scale (EDS-21)**

The Exercise Dependency Scale-21 (EDS-21) (Hausenblas & Downs, 2002) is a self-report measure that assesses for exercise dependency consistent with criteria outlined in the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV; APA, 2013). The EDS-21 consists of the following seven subscales: Withdrawal Effects (e.g., “I exercise to avoid feeling tense”), Continuance (e.g., “I exercise when injured”), Tolerance (e.g., “I continually increase my exercise duration to achieve the desired effects/benefits"), Lack of Control (e.g., "I am unable to reduce how often I exercise"), Reductions in Other Activities (e.g., "I choose to exercise so that I can get out of spending time with family/friends"), Time (e.g., "I spend a lot of time exercising"), and Intention (e.g., "I exercise longer than I plan"). Participants indicate their endorsement of each item on a 6-point Likert scale from "never" (1) to "always" (6). A higher score reveals more exercise dependence symptoms. Based on their responses, individuals are placed into one of three categories: at risk for exercise dependency, non-dependent symptomatic, and non-dependent asymptomatic on each of the 7 DSM criteria. The categorisation is generated by a scoring manual (Hausenblas & Downs, 2002) in which items or combinations of items determine if an individual would be classified in the dependent, symptomatic, or asymptomatic range. Individuals who are classified into the dependent range on 3 or more of the DSM criteria are classified as exercise dependent. The dependent range is operationalised as indicating a score of 5 or 6 for that item. Individuals who scored in the 3 to 4 range are classified as symptomatic, and theoretically can be considered at-risk for exercise dependence. Finally, individuals who score in the 1-2 range are classified as asymptomatic. The EDS-21 has both good concurrent validity (Szabo & Griffiths, 2007) and high internal consistency, reliability, and convergent validity (Hausenblas & Downs, 2002). In the present study, the Cronbach's α was .92 for the EDS-21 total, .84 for the Withdrawal Effects subscale, .89 for the Continuance subscale, .81 for the Tolerance subscale, .85 for the Lack of Control subscale, .73 for the Reductions in Other Activities subscale, .79 for the Time subscale, and .91 for the Intention subscale.

**Eating for Muscularity Scale (EMS)**

The Eating for Muscularity Scale (EMS) (Cooper, Griffiths, & Burns, 2019) is a 27-item self-report measure that assesses for muscularity-oriented disordered eating pathology. Muscularity-oriented disordered eating is defined as “eating and eating related behaviours and attitudes aimed to increase muscularity and leanness. Engaging in these behaviours leads to distress, dysfunction, and/or negative health outcomes” (Cooper, Griffiths, & Burns, 2019, p. 453). The EMS is scored on a 7-point Likert scale from “no days” to “every day”. Higher scores indicated higher levels of muscularity-oriented disordered eating psychopathology. The EMS consists of nine subscales: Preoccupation (e.g., “I give a lot of time and thought to becoming more lean”), Diet Gain (e.g., “I must eat mostly protein-based foods (e.g. red meat, fish, chicken, etc.)”, Diet Loss (e.g., “I have eaten a low fat diet”), Dietary Restraint (e.g., “I have specifically avoided processed foods”), Excessive Attention (e.g., “I have weighed ingredients when preparing meals and snacks”), Functional Impairment (e.g., “My eating regime interferes with my work/studies”, Health Risks (e.g., I have used dieting methods that I know are unhealthy”), Exercise Compensation (e.g., “I add extra exercise into my normal regime if I have eaten too much 'junk food'”), and Negative Affect (e.g., “I felt anxious if I was not able to prepare my meals and snacks in advance”). Participants rated the number of days in the previous four weeks in which they engaged in each item (0 = no days, 1= 1-5 days, 2 = 6-12 days, 3 = 13-15 days, 4 = 16-22 days, 5 = 23-27 days, 6 = every day). The EMS has demonstrated both high levels of internal consistency (Cronbach’s α = .96) and strong test-retest reliability (*r* = .92) (Cooper, Griffiths, & Burns, 2019). In the present study, the Cronbach’s α was .91 for the total EMS, .42 for the Preoccupation subscale, .45 for the Diet Gain subscale, .30 for the Diet Loss subscale, .32 for the Dietary Restraint subscale, .74 for the Excessive Attention subscale, .67 for the

Functional Impairment subscale, .55 for the Health Risks subscale, .68 for the Exercise Compensation subscale, and .65 for the Negative Affect subscale.

**Visual Body Scale for Men (VBSM)**

Figure rating scales are visual tools used to measure body image. From the presented bodies, participants are asked to select the body that best approximates the visual appearance of their own body, and in separate trials, the body that best corresponds to how they would ideally wish their body to appear. The difference between the values of perceived and ideal bodies are then used as an index of body dissatisfaction.

The Visual Body Scale for Men (VBSM) (Talbot, Cass, & Smith, 2019) is one measure that assesses perceived and desired body shape in men. The VBSM consists of two figural rating scales: the VBSM-Muscularity (VBSM-M) and the VBSM-Body Fat (VBSM-BF). For this experiment, only the VBSM-M was used. The VBSM-M consists of 10 male bodies increasing in muscularity (as indicated by the fat free mass index [FFMI]), ranging from 16.5 to 30 (Figure 1). FFMI is a biometric measure of a male's degree of muscularity (Pope, Phillips, & Olivardia, 2000). Typically, a FFMI that exceeds 25 (body g: Figure 2) represents a level of muscularity that would be extremely difficult to achieve without the use of anabolic–androgenic steroids (Kouri, Pope, Katz, & Oliva, 1995; Pope Jr et al., 1997).


Figure 1. VBSM-M. bodies (a–j) consistently increase in FFMI by 1.5 kg/m$^2$, ranging from 16.5 kg/m$^2$ (body a) to 30 kg/m$^2$ (body j). FFMI: fat-free mass index.

According to the criterion for adequate test–retest reliability (coefficient ≥ 0.70) (Terwee et al., 2007), the VBSM-M has good test-retest reliability. From the intraclass correlation coefficient (ICC) a good agreement was indicated for Perceived (ICC=0.75, $p$ < .001, CI = 0.50-0.87), Desired (ICC=0.88, $p$ < .001, CI = 0.77-0.94) and Discrepancy (ICC=0.83, $p$ < .001, CI = 0.68-0.91) scores of the VBSM-M (Talbot et al., 2019). Additionally, the VBSM-M has demonstrated high concurrent and convergent validity (Talbot et al., 2019). Discrepancy scores were calculated via the following formulas: VBSM-M discrepancy = “VBSM-M desired” minus “VBSM-M perceived”. For example, if a participant were to select their perceived muscularity using the VBSM-M as body c (FFMI 19.5 kg/m$^2$), and their desired body as body h (FFMI 27.0 kg/m$^2$), then their VBSM-M discrepancy score would be 27-19.5 = 7.5 kg/m$^2$.

**New Somatomorphic Matrix–Male (NSM-M)**

The New Somatomorphic Matrix–Male (NSM-M) (Talbot, Smith, Cass, & Griffiths, 2018) (see Figure 1) is a perceptually equivalent and modified version of Somatomorphic Matrix Modification scale, (Cafri, Roehrig, & Thompson, 2004). The NSM-M a bidimensional computerised body image test that assesses satisfaction and perceptual accuracy with respect to muscularity (y axis) and body fat (x axis).

Once presented with the NSM-M, participants were asked the following: (a) “Please click the location on the grid that best corresponds to your actual body”, and (b) “Please click the location on the grid that best corresponds to your ideal body (i.e., the body you would most like to have as your own)”. According to criterion for adequate test–retest reliability (coefficient ≥ 0.70) (Terwee et al., 2007), the NSM-M has good test-retest reliability. From the intraclass correlations coefficients (ICC) a good agreement was indicated for perceived, ideal, other, and discrepancy across both NSM-M body fat and NSM-M muscularity measures (ICC = 0.78-0.95, $p < .001$).

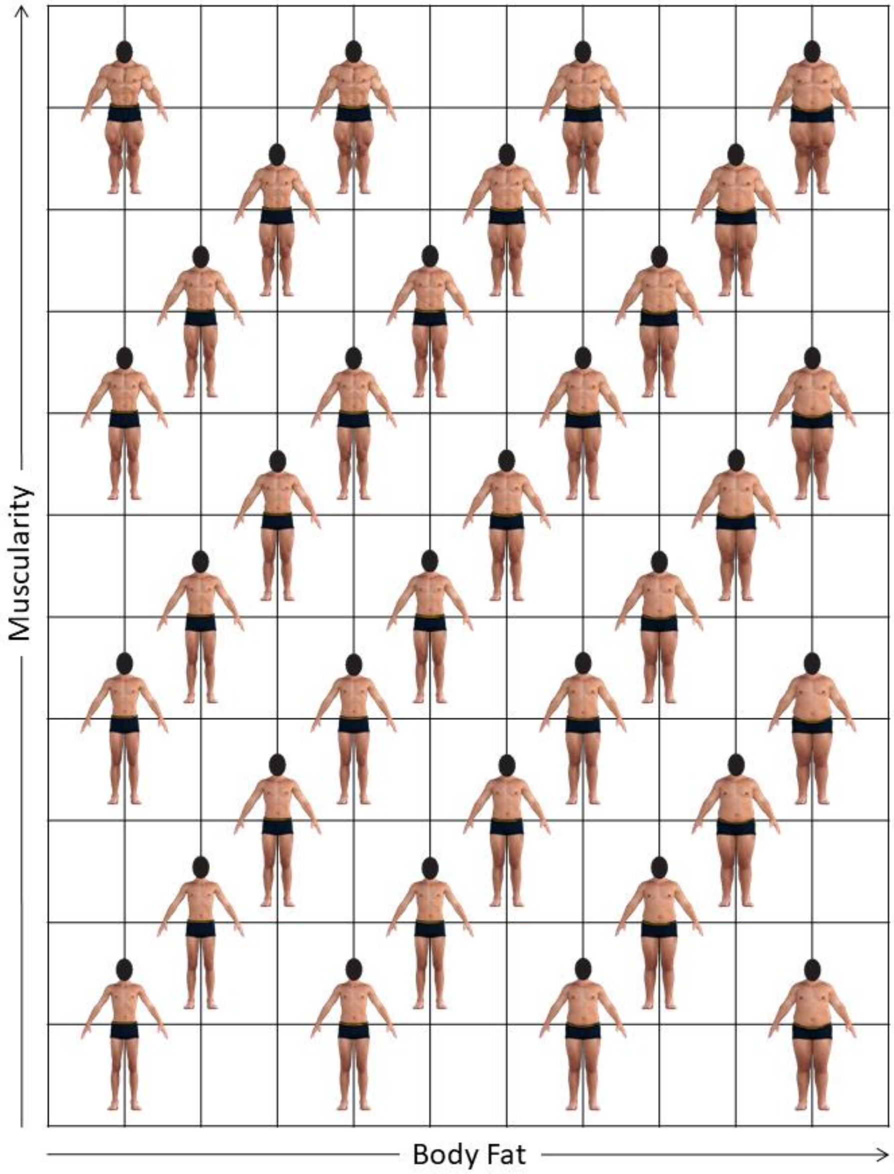



Figure 2. The New Somatomorphic Matrix–Male (NSM–M). The x-axis displays body fat percentage ranging from 4 to 40%, increasing in increments of 4%. The y-axis presents fat-free mass index ranging from 16.5 to 30 kg/m$^2$ (36.4–66.1 lbs/m$^2$), increasing in increments of 1.5 kg/m$^2$.

**Appearance and Performance Enhancing Supplement/Substance Scale (APES)**

The Appearance and Performance Enhancing Supplement/Substance Scale (APES) (Cooper, Hicks, & Griffiths, 2019) is a 20-item self-report survey developed to evaluate individual use of supplements and substances for the purpose of body modification and enhanced performance. The APES consists of two subscales, a supplement subscale (items 1-7), and a substance subscale (items 8-20). For the purpose of this research only the supplement subscale was employed. The APES measures use over the past 3 years to capture cyclical use of appearance and performance-enhancing drugs (APED) as is common in MD populations. Each item is rated on a 4-point Likert scale stating “How much time you have used each of these supplements in the past 3 years” from “never” (0) to “a lot” (3) (where 0 = never, 1 = a little (0-1 month), 2 = moderate (1-6 months), 3 = a lot (6 months or more)). There is also an option for individuals to report other supplements used. Higher scores on this subscale indicate higher levels of supplement use. Responses were totalled to calculate the scores on the Supplement subscale. The APES has demonstrated both high levels of internal consistency of the total measure (Cronbach’s $\alpha$ = .78), as well as the Supplements subscale (Cronbach’s $\alpha$ = .82) (Cooper, Hicks, & Griffiths, 2019). Additionally, the APES has shown good reliability for the Supplements subscale ($r = .88$, $p < .001$) (Cooper, Hicks, & Griffiths, 2019). In the present study, the Cronbach’s $\alpha$ was .82 for the APES supplement subscale.

**Female Questionnaire Measures**

**Eating Disorder Inventory-III (EDI-3)**

The Eating Disorder Inventory-III (EDI-3) was administered and scored according to the manual (Garner, 2004), to measure the presence of affective, behavioural, and/or cognitive ED symptomatology. The EDI-3 consists of 91 items across 12 primary scales. This is a well-validated, frequently used scale, currently in its third edition. Three of the primary scales are called ED Risk Scales: Drive for Thinness (7 items, e.g., “I think about dieting”), Bulimia (8 items, e.g., “I stuff myself with food”), and Body Dissatisfaction (10 items, e.g., “I think that my stomach is too big”). They describe some of the central features of an ED such as the overestimation of one's weight and body size and the drive to be thin, which increase the risk of developing ED (Fairburn, 2008; Stice, Marti, & Durant, 2011; Stice, Ng, & Shaw, 2010). The remaining nine scales are called Psychological Scales (Low Self-esteem, Personal Alienation, Interpersonal Insecurity, Interpersonal Alienation, Interoceptive Deficits (7 items, e.g., "When I am upset, I don't know if I am sad, frightened, or angry"), Emotional Dysregulation, Perfectionism, Asceticism and Maturity Fears) and describe basic concepts and difficulties in different areas. The participants respond to the items on a 6-point Likert scale from "never" (0) to "always" (4) (where 0 = never, 0 = rarely, 1 = sometimes, 2 = often, 3 = usually, 4 = always). The EDI-3 has demonstrated good levels of reliability across all subscales (Cronbach's $\alpha = .90$–$.97$; test–retest $r = .98$) (Garner 2004; Wildes et al. 2010). In the present study the Cronbach α was 0.91 for the Drive for Thinness subscale, 0.89 for the Bulimia subscale, 0.92 for the Body Dissatisfaction subscale, 0.91 for the Low Self-esteem subscale, 0.83 for the Personal Alienation subscale, 0.85 for the Interpersonal Insecurity subscale, 0.86 for the Interpersonal Alienation subscale, 0.91 for the Interoceptive subscale, 0.84 for the Emotional Dysregulation subscale, 0.83 for the Perfectionism subscale, 0.75 for the Asceticism subscale, and 0.79 for the Maturity Fears subscale.

**Objectified Body Consciousness Scale (OBCS)**

The Objectified Body Consciousness Scale (OBCS; McKinley & Hyde, 1996) was developed to assess three aspects of objectified body consciousness including body surveillance, body shame, and beliefs about body control. Each subscale has 8-items and is scored on a 7-point Likert scale ranging from "strongly disagree" (1) to "strongly agree" (7) and subscale scores are derived by averaging responses across all items pertaining to that subscale. Higher scores on this measure reflect greater objectification. The OBCS has demonstrated good levels of internal consistency across all subscales (Cronbach's α =.72 - .89) (McKinley & Hyde, 1996). In the present study the Cronbach α's for these subscales were α = 0.87 (surveillance), α = 0.83 (body shame) and α = 0.88.

### Objectified-Other Body Consciousness Scale (OOBCS)

A modified version of the OBCS, the Objectified-Other Body Consciousness Scale (OOBCS), was designed to measure the extent to which participants objectify other people's bodies in everyday life. The OOBCS was adapted from the OBCS by rephrasing each of the items to refer to other people, rather than one's self. The same method has been used in previous studies (e.g., Strelan, & Hargreaves, 2005; Lindner, Tantleff-Dunn, & Jentsch, 2012), although they adapted only the OBCS Surveillance subscale to refer to other bodies (five items from the OBCS Control subscale were not adapted into the OOBCS as they referred to bodies in general, rather than to one's own body, so it was not necessary to ask them twice). Each subscale has 8-items and is scored on a 7-point Likert scale ranging from "strongly disagree" (1) to "strongly agree" (7) and subscale scores are derived by averaging responses across all items pertaining to that subscale. Higher scores on this measure reflect greater objectification of others and the items reflect the extent to which a woman notices the appearance of other women in her daily life.). In the present study the Cronbach α's for these subscales were α = 0.77 (surveillance), α = 0.74 (body shame) and α = 0.83.

### Body Image Concern Inventory (BICI)

The Body Image Concern Inventory ((BICI) Littleton, Axsom & Pury, 2005) is a measurement of dysmorphic concerns related to self-perceived flaws in participants' physical appearance. Dysmorphic concern characterizes individuals with BDD and is common among people with EDs. It contains 19 items related to dissatisfaction and concern about appearance, reassurance seeking, social concerns, excessive monitoring and avoidance related to appearance. Items contain brief descriptions that investigate perceived defects in appearance, attempts to monitor or hide them, and seeking reassurance about them. For each item, respondents were asked to rate how often they had the described feeling or performed the described behaviour on a 5-point Likert scale ranging from “never” (1) to “always” (5). The total score on the scale ranges from 19-95. Higher scores indicate higher dysmorphic concern. A cut-off of 72 was found to have 96% sensitivity and 67% specificity for distinguishing individuals who met diagnostic criteria for BDD or bulimia nervosa from those with subclinical BDD/ED symptoms (Littleton et al., 2005). This questionnaire has demonstrated good internal consistency (Cronbach's alpha = .93) (Littleton et al., 2005). In the present study, the BICI total Cronbach’s α was .96.

## Body puzzle task

The body puzzle task was given to all participants except for the final 7 participants (2 women high risk ED, 3 men high risk MD, and 2 men low risk MD). These 7 participants completed a different, online body puzzle task instead (described in Chapter 5) to minimise lab time to comply with new COVID-19 rules.

The body puzzle task was used to measure how effectively body representations are stored in memory; this novel task was developed specifically for this study with the intention of assessing participant’s configural processing, which involves processing the structural and spatial relations between body parts (Reed, Stone, Grubb, & McGoldrick, 2006). Two figures of bodies (one male, one female), with healthy-looking body fat composition and muscularity, were rendered using Daz Studio 4.1 (www.Daz3d.com). Healthy figures of bodies were used to avoid exposing particpants to images they could consider triggering or harmful. These figures were then colour-printed onto white A4 paper and segmented into ten parts (identically for each figure; see Figure 3), as follows: head; upper left arm; upper right arm; lower left arm; lower right arm; torso, upper left leg; upper right leg; lower left leg; lower right leg. The outline of the body within each designated segment was cut up into a separate piece, for each participant to stick, one at a time, using a glue stick, onto separate sheets of A4 transparency paper (see Figure 3). Both the original figures, which were also presented to participants on white A4 paper, and the figures made of composite parts (before segmentation), were 23.5cm x 16cm in size. Body puzzle task scores (how closely in configuration the recreated body matches the original) could potentially be obtained in a number of different ways. To control for any potential experimenter bias, for this study, we asked a separate group of participants to rate how similar the participants recreated images were to the original image on a visual analogue scale from 0 (not at all similar in arrangement) to 100 (extremely similar in arrangement). This will be described in Results.

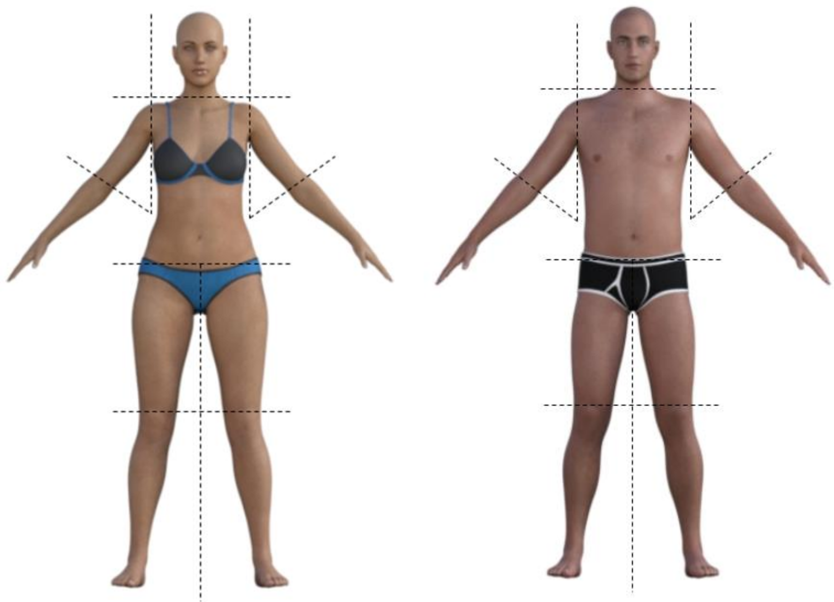


Figure 3. Stimuli used in the body puzzle task. The dotted lines demonstrate where the ten segment divisions were made for each figure.

## EEG Stimuli

### Passive viewing task stimuli for Experiment 1

To obtain realistic body stimuli representative of the bodies that are likely to be encountered in everyday life, 100 photographs of bodies (50 female, 50 male) and 50 photographs of houses were downloaded from the World Wide Web. To simulate realistic viewing further, body stimuli were selected to depict an array of shapes and sizes, classified as either desirable or undesirable. Images differing in background colour were selected, which were then cropped and edited to obtain a similar amount of background space across the different images and to ensure identical vertical size across all images. All images were matched in relation to visual complexity (i.e. each showing only one body or one house, instead of scenes) as this has been shown to affect attentional processes (Miller & Fillmore, 2010). Houses were choses as they are known to provide a figure similar in complexity to faces with neutral salience (Li et al., 2015). Luminosity has been suggested to be one of the most important sources of perceptual processing (Valberg, 2005), and may have a strong effect on brain activity during visual processing. Apart from the content of visual stimuli, the luminosity of visual stimuli may also have the potential to influence neural activity. Therefore, in this study luminosity was assessed and controlled for using photo editing software to ensure mean image brightness was equal across all groups (desirable males, undesirable males, desirable females, undesirable females, and houses) (see Fig. 5 for examples). All participants completed the passive task using a Dell 2407WFP-HC (monitor resolution 1920 x 1200 pixels; refresh rate 59 Hz).

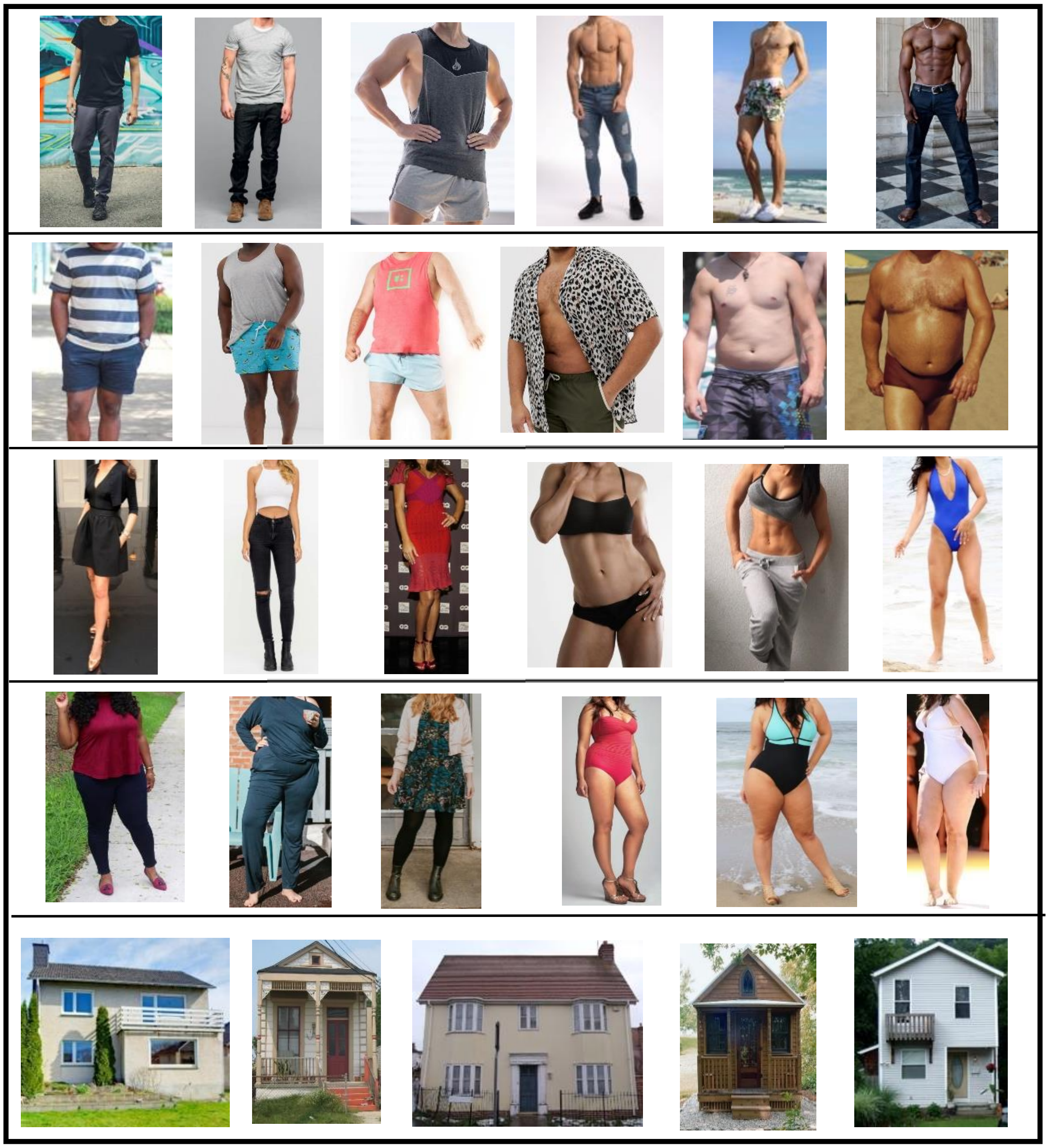


Figure 4. Example stimuli used in Experiment 1 (Top to bottom: desirable male bodies; undesirable male bodies; desirable female bodies; undesirable female bodies; and houses).

## Inversion task stimuli for Experiment 2

The images were a mixture of front and back views, and heads were cut off just below the chin to ensure that any inversion effects found were in response to bodies and not to faces (Groves, Kennett, & Gillmeister, 2018; Minnebusch & Daum, 2009). The stimuli were rendered using Daz Studio 4.1 (www.Daz3d.com) using the male and female three-dimensional model Genesis 8.0. Stimuli were rendered from both front and rear-view perspectives and then scaled to various increments to create bodies with differing body compositions (achieved using the built-in Daz Studio 4.1 scaling in the following features: muscularity (0-70%), body fat (0-70%), and emaciation (0-70%)). All participants completed the inversion task using a Dell 2407WFP-HC (monitor resolution 1920 x 1200 pixels; refresh rate 59 Hz). Example stimuli are shown in Figure 4.

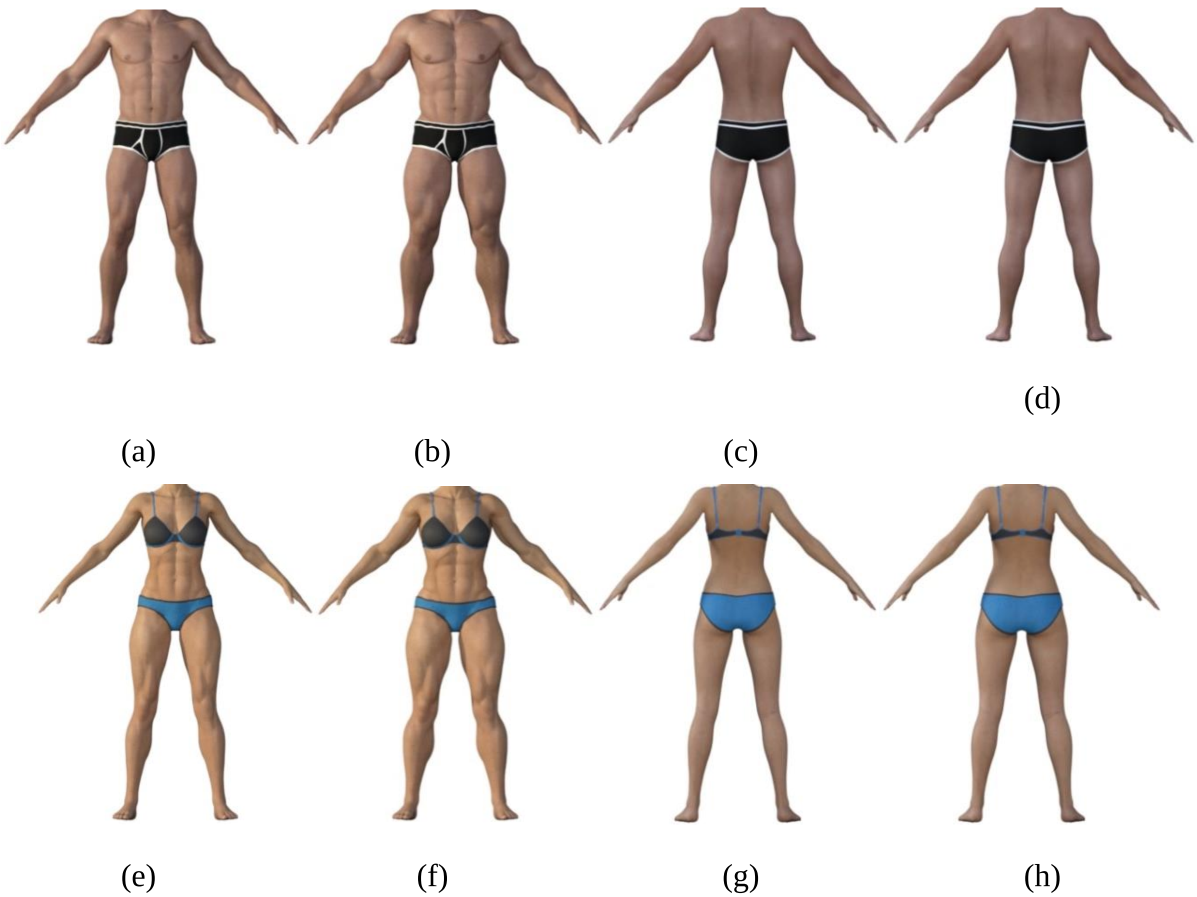


Figure 5. Examples of stimuli used in the inversion task, which differ in muscularity, body fat, and emaciation details; (a) Male front view (muscularity: 0; body fat: 0); (b) Male front view (muscularity: 60; body fat: 60); (c) Male rear view (emaciation: 0; body fat: 0); (d) Male rear view (emaciation: 0; body fat: 25); (e) Female front view (muscularity: 0, body fat: 0); (f) Female front view (muscularity: 60; body fat: 60); (g) Female rear view (emaciation: 0; body fat: 0); (h) Female rear view (emaciation: 0; body fat: 25).

## Procedure

A standardized overview of procedures was given to participants, and written consent was obtained. Digital scales were used to weigh participants, and a tape measure was used to measure height and waist circumference. To avoid causing the participants any harm, participants were not told their body measurements. The final 7 participants (2 women high risk ED, 3 men high risk MD, and 2 men low risk MD), however, were asked to indicate those measures along with their demographic information within the online questionnaires to minimise lab time to comply with new COVID-19 rules. Participants then completed the questionnaires either on a lab computer or online before coming into the lab. Questionnaires comprised questions about demographic information, mental health diagnoses, and either the MDDI, SATAQ-4R-Male, EDS-21, EMS, NSM-M, VBSM-M and APES scales (males only), or EDI-3, OBCS, OOBCS, and BICI scales (females only). Participants then completed the body puzzle task either on a lab desk or online. In the lab, participants were shown the complete figure of the first body (female or male) an A4 sized paper, with the presentation order being counterbalanced across the sample to control for any practice effects. The participants were then instructed to look at the figure for as long as they needed and until they felt ready to complete the task. The complete figure was then removed. Participants were given one of the ten cut-up parts of the figure (see figure 3) and were instructed to stick that part with a glue stick, onto a sheet of A4 transparency paper, in the location which they thought the body part had been located on the original figure. After the participant had stuck down the body part, the piece of transparency paper was removed and a blank sheet of transparency paper was provided for them to stick down the next body part, until all ten parts had been completed. There were no time constraints for completion of this task. The order of presentation of the ten body parts was the same for each participant, namely: upper right leg; upper left arm; head; upper left leg; lower right arm; lower left leg; torso; lower right leg; upper left arm. To control for order effects, the order of body parts was chosen such that participants did not re-create the image outwards from the torso, nor were participants ever given adjacent body parts. Participants were told that the aim of the task was to re-create a figure of the body they had just observed to the greatest accuracy possible. Following completion of the first figure, the same procedure was followed for the second body (the opposite sex to the first figure).

Participants were then fitted with an EEG cap and completed the two computer-based tasks. They first completed the more demanding body inversion task (Experiment 2), followed by the less demanding passive viewing task (Experiment 1).

For the body inversion task, participants were given task instructions that detailed that they were to complete the task as accurately and as quickly as possible. The task was a body discrimination task where participants had to indicate which of two images of bodies replicated a body they had previously seen, similar to Groves et al. (2020) and Urgesi et al., (2012). Following this, participants were then instructed to fixate on the centre of a grey screen. A black fixation cross was presented centrally for 1000ms in each trial, followed by an image of a body (either a front or back view, presented upright or inverted) for 500 ms. This was then replaced by a mask for 500 ms (to avoid participants retaining aftereffects of the image on their retina) and was followed by two images of bodies presented next to each other, in the same view and orientation as the first image (front or back, upright or inverted). One of these images was identical to the previous image shown, and the other differed in terms of body fat composition or muscularity. The two images were presented on the screen until the participant made a response. To make this task challenging, pairing was such that the images looked similar but discernibly different, that is, they were always between one and two body fat and/or muscularity increments away from the original image within our stimulus set (see Figure 5 for example stimuli). Participants were instructed to hold the computer mouse with both hands, to minimize the possibility of hemispheric artifacts from preparing responses with one hand only, and to left click with their left hand if they thought the image presented on the left was identical to the single image they had just been shown, and vice versa for the right. Figure 6 shows the trial sequence. Sixty-eight trial types (17 male upright, 17 male inverted, 17 female upright, 17 female inverted) were each shown three times, giving 204 trials in total. Trial types were shown in random order to avoid any order and practice effects, and participants received feedback every 30 trials on their cumulative correct performance speed, their cumulative percentage of correct responses, and the total number of trials completed. The task took approximately 15 minutes to complete.

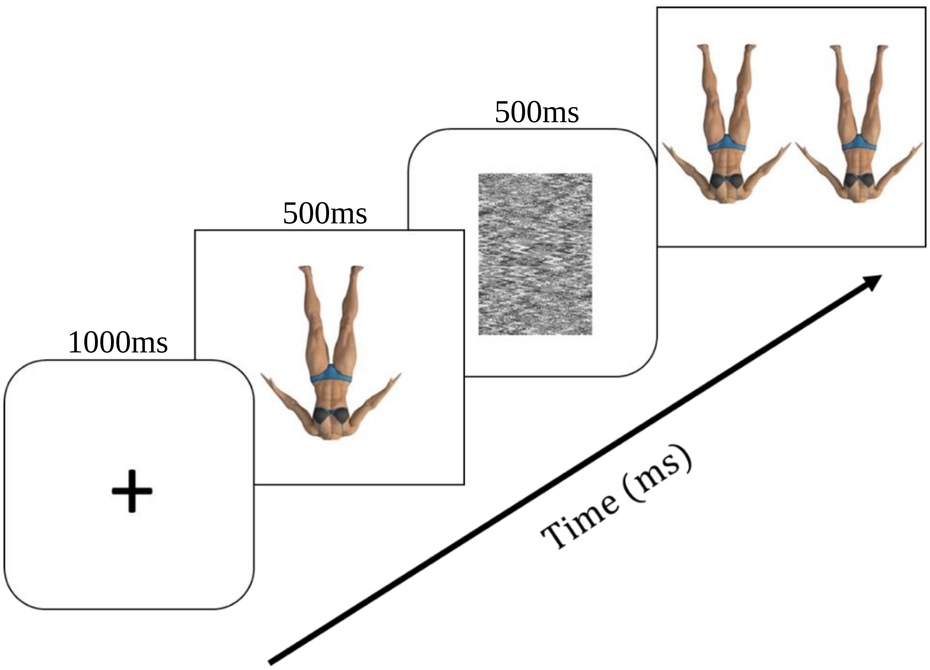



Figure 6. Trial sequence shown in the body inversion task. The last screen was shown until a response was made.

For the passive viewing task, participants were asked to fixate on the centre of a white computer screen. A black fixation cross was presented centrally until it was replaced, for 1000ms on each trial, by a picture. After each 1000-ms picture presentation, there was a random inter-trial interval of between 300ms and 700ms which separated individual trials. The picture was either of a male or female body, a house, or occasionally an animal. Participants were instructed to press the space bar with both hands (to avoid hemispheric artifacts from response preparation with one hand) as quickly as possible whenever they saw an animal picture (see Groves et al., 2017). Participants were shown 170 images of bodies, houses, and animals. These images were shown twice, with the second presentation left-right reversed. Thus, the participants completed 340 trials (50 male bodies; 50 female bodies; 50 houses; 20 animals). To control for order effets, stimuli were shown in random order with a cumulative summary of animal detection times and errors displayed during inter-block intervals, which occurred every 50 trials. The task took approximately 12 minutes to complete.

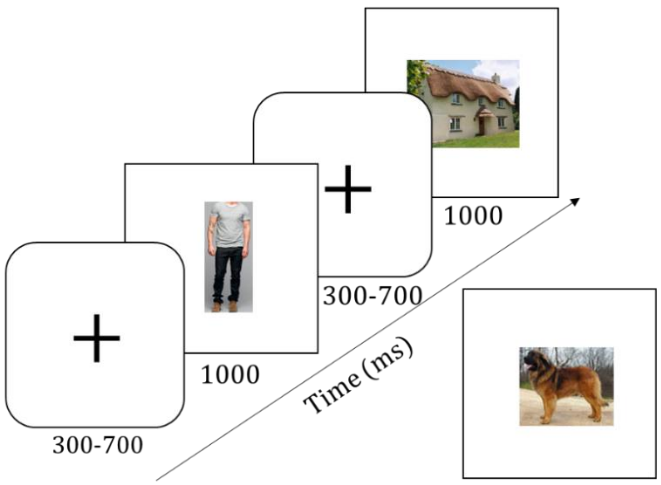



Figure 7. Computer-based oddball (animal) detection task (similar to Groves et al., 2017) with example trial sequence. Far right image shows an example of an animal image.

## EEG acquisition

Recording and offline analysis of EEG and EOG data was conducted with Neuroscan Synamps2 system (Compumedics, Melbourne, Australia) and BrainVision Analyzer software

(BrainVision Analyzer, Version 2.2.0, Brain Products GmbH, Gilching, Germany). Continuous EEG was sampled between 0.05 and 100 Hz at a rate of 1000 Hz from 63Ag/AgCl electrodes placed within a scalp cap according to the international 10–10 system (EASYCAP GmbH, Herrsching, Germany) as well as on the right earlobe for later re-referencing. Online, the signal was referenced to the left earlobe with all electrode impedances kept below 35 kΩ. Bipolar channels recorded vertical (VEOG) and horizontal (HEOG) electrooculogram from above and below the midpoint of the right eye and beside the outer canthi of both eyes. Offline, continuous EEG was high-pass filtered at 0.1 Hz, low-pass filtered at 40 Hz (24 dB slope), with a 50 Hz notch filter to remove excessive noise, using zero phase shift Butterworth filters, and then re-referenced to the average of the two earlobes, which is preferable to using the average reference for showing affective processing at components like LPP (see Hajcak et al., 2012).

## Segmentation

The data were epoched from 100 ms before visual stimulus onset (the single stimulus on each trial) to 1000 ms after. Epochs were baseline-corrected against the mean voltage of the 100-ms pre-stimulus time window.

## Artifact detection

Epochs with artifacts (events exceeding +/-100µV between 50 ms before and 400 ms after stimulus onset, relative to the 100-ms pre-stimulus baseline; these were typically eye blinks) were removed from the dataset. This maximised the number of trials included in averages while ensuring that averages did not contain trials where the onset of visual stimuli may have been missed due to blinking. For one (male, low risk) participant, this method excluded more than

20% of trials from further analysis. In order to avoid excluding this participant, some excluded epochs were manually re-included into the dataset provided the artifacts occurred at electrodes outside the central and posterior scalp regions of interest and were not blinks (suggesting missed visual stimulus onsets). An average of 8% of trials (range 0-19% across participants) were excluded due to artifacts.

## Electrode selection and ERP data extraction

Electrode and time window selection were based on grand averaged waveforms collapsed over all conditions, separately for each task (see Figure 8). For both passive (Experiment 1) and inversion tasks (Experiment 2), mean N170/VPP responses were investigated in each participant at occipital-parietal and vertex electrodes, which have been linked to processing human bodies (see Kropotov, 2016; Groves et al., 2017, 2018; Minnebusch, Keune, Suchan, and Daum, 2010). N170 peaks were evident over electrodes P3/4, P5/6, P7/8 PO7/8, PO5/6, PO3/4, and O1/2, all of which are frequently implicated in body processing (for an overview see Groves et al., 2018). The VPP, however, was not prominent in either task (see Figure 8) and for this reason, subsequent ERP analyses will focus on N170 only. For the passive viewing task, mean ERP amplitudes were extracted separately for desirable and undesirable male and female bodies at these seven electrodes, within a time window centred on the peak of the N170 (130 - 180ms). For the inversion task, mean ERP amplitudes were extracted separately for upright and inverted male and female bodies at these seven electrodes, within the slightly earlier time window of 110 - 160ms, which was centred around the N170 peaks at these electrodes during this task. Signals from all 7 electrodes in each hemisphere were averaged onto a left-hemisphere and a right-hemisphere electrode cluster to reduce variables for statistical analyses to contain the multiple comparison problem (Cooper, Simpson, Till, Simmons, & Puzzo, 2013; Maris & Oostenveld, 2007). Finally, for the passive viewing task only, the LPP was computed across a central electrode cluster (FCz, Cz, CPz) from 400 to 1000 ms. Again, signals from all 3 electrodes were averaged to reduce variables for statistical analyses.

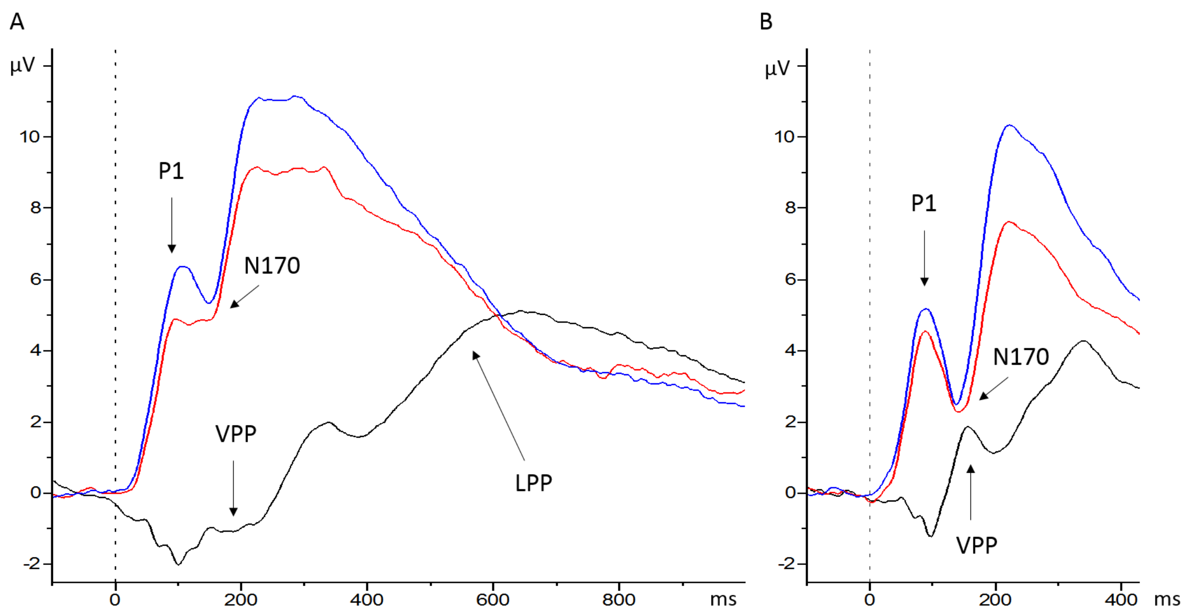



Figure 8. Grand averaged ERP waveforms collapsed over all conditions and participants for passive viewing (Panel A) and body inversion tasks (Panel B) at vertex electrode Cz (black lines), left occipital-parietal electrode PO7 (red lines) and right occipital-parietal electrode PO8 (blue lines). ERP components of interest are indicated by arrows.

## Correlational analyses

Inversion task. In order to investigate the links between electrophysiology, behaviour and attitudes towards one's own body (dysmorphic concern, exercise dependence, eating behaviours and self-objectification), Pearson's *r* correlational analyses were planned between demographic factors; questionnaire scores; behavioural and ERP inversion effects.

Passive viewing. In order to investigate the links between electrophysiology and attitudes towards one's own body (dysmorphic concern, exercise dependence, eating behaviours and self-objectification), Pearson's / Spearman's *r* correlational analyses were planned between demographic factors; questionnaire scores and ERP N170 and LPP gender-sensitive effects.

Correlational analyses were conducted across groups, since evidence suggests that symptoms of body image related disorders occur on a spectrum (Bienvenu et al., 2000; Shisslak, Crago, & Estes, 1995). Other studies that have tested groups with different eating pathologies have also used this method (e.g., Groves et al., 2017; Mitchison, Crino, and Hay, 2013).

Ratings for the body puzzle task were not entered into correlational analyses because not all participants had completed this task in the same way.

The false discovery rate method of correction for multiple comparisons (Benjamini & Hochberg, 1995) was applied to correlation results, results that did not survive correction are not reported.

# Results

## Age and questionnaire results

Descriptive statistics for the measured variables were separately analysed for men (Table 2) and women (Table 3). Independent samples t-tests were conducted to assess any difference in the measured variables between the groups (High risk vs Low risk). All male participants completed the EDS-21, EMS, VBSM, NSM, and APES. All female participants completed the EDI-3, OBCS, OOBCS, and BICI.

## Men

For men, differences were found between groups in internalisation of appearance ideals, with the High risk MD group reporting significantly higher levels of desirability to attain a muscular figure ($t(33) = 2.71$, $p = .011$, see Table 2), and greater appearance pressures emanating from media ($t(33) = 2.76$, $p = .009$, see Table 2) compared to the Low risk MD men. Differences were also found between groups' eating behaviours, with the High risk MD men reporting significantly higher levels of muscularity-oriented disordered eating pathology (Total EMS: $t(33) = 2.52$, $p = .017$), enhanced pre-occupation towards enhancing muscularity ($t(33) = 2.33$, $p = .026$), diet gain ($t(33) = 2.20$, $p = .035$), heightened excessive attention towards eating ($t(33) = 2.07$, $p = .047$), increased functional impairment ($t(33) = 3.18$, $p = .003$), and greater diet related health risks ($t(33) = 2.09$, $p = .045$) compared to the Low risk MD men. Please note, however, that because internal consistence was below acceptable levels ($\alpha < .6$) for pre-occupation, diet gain and health risks, conclusions about group differences on these EMS subscales must be drawn with caution. There were differences between groups in exercise dependence, with the High risk MD men reporting significantly higher levels of total exercise dependence ($t\ (33) = 2.07$, $p = .047$), reduction in other activities ($t\ (33) = 2.10$, $p = .044$), time spent exercising ($t\ (33) = 2.29$, $p = .029$), and intention effects ($t\ (33) = 2.21$, $p = .034$). There was no significant difference between the High and Low risk MD groups in appearance and performance enhancing supplement usage ($t\ (33) = 0.84$, $p = .409$), body dissatisfaction measured via body shape discrepancy (VBSM, ($t\ (33) = 0.94$, $p = .355$)), body fat discrepancy ($t\ (33) = 0.89$, $p = .382$), and muscularity discrepancy ($t\ (33) = 0.69$, $p = .609$). Mean scores for both risk groups on the SATAQ-4R, EMS, APES, VBSM, NSM-M, and EDS are reported in Table 2.

Table 2 Mean scores and standard deviations for High risk MD men and Low risk MD men across measured variables.

| Measures | Low risk MD (*n* = 16) | | High risk MD (*n*=19) | | Group Comparison (T-test) |
|---|---|---|---|---|---|
| | Mean | *SD* | Mean | *SD* | |
| SATAQ-4R | | | | | |
| Internalisation: Thin/Low Body Fat | 4.38 | 2.16 | 4.63 | 2.27 | $t$ (33) = 0.34, $p$ = .735 |
| Internalisation: Muscular | 14.25 | 2.86 | 16.95 | 2.99 | $t$ (33) = 2.71, $p$ = .011 |
| Internalisation: General Attractiveness | 7.81 | 1.64 | 8.47 | 1.07 | $t$ (33) = 1.43, $p$ = .162 |
| Pressures: Family | 9.56 | 5.43 | 8.74 | 3.84 | $t$ (33) = 0.53, $p$ = .603 |
| Pressures: Peers | 8.81 | 4.39 | 11.26 | 4.36 | $t$ (33) = 1.65, $p$ = .108 |
| Pressures: Significant Others | 8.88 | 5.37 | 10.26 | 5.51 | $t$ (33) = 0.75, $p$ = .458 |
| Pressures: Media | 12.88 | 8.00 | 20.11 | 7.47 | $t$ (33) = 2.76, $p$ = .009 |
| Total EMS | 24.13 | 18.68 | 43.63 | 25.81 | $t$ (33) = 2.52, $p$ = .017 |
| Preoccupation | 1.29 | 0.80 | 2.07 | 1.12 | $t$ (33) = 2.33, $p$ = .026 |
| Diet Gain | 1.96 | 1.59 | 2.96 | 1.10 | $t$ (33) = 2.20, $p$ = .035 |
| Diet Loss | 1.13 | 1.12 | 1.81 | 1.14 | $t$ (33) = 1.67, $p$ = .104 |
| Dietary Restraint | 0.81 | 1.14 | 1.46 | 1.24 | $t$ (33) = 1.59, $p$ = .121 |
| Excessive Attention | 1.15 | 1.50 | 2.21 | 1.53 | $t$ (33) = 2.07, $p$ = .047 |
| Functional Impairment | 0.04 | 0.11 | 0.90 | 1.07 | $t$ (33) = 3.18, $p$ = .003 |
| Health risks | 0.08 | 0.23 | 0.56 | 0.89 | $t$ (33) = 2.09, $p$ = .045 |
| Exercise Compensation | 0.77 | 1.15 | 1.00 | 1.19 | $t$ (33) = 0.58, $p$ = .567 |
| Negative Affect | 0.81 | 0.80 | 1.58 | 1.78 | $t$ (33) = 1.59, $p$ = .121 |
| APES | | | | | |
| Supplement | 10.13 | 4.63 | 11.58 | 5.50 | $t$ (33) = 0.84, $p$ = .409 |
| VBSM-M | | | | | |
| Perceived | 5.19 | 1.42 | 4.95 | 1.81 | $t$ (33) = 0.43, $p$ = .670 |
| Ideal | 7.31 | 1.20 | 7.47 | 1.31 | $t$ (33) = 0.38, $p$ = .708 |
| Discrepancy | 2.13 | 1.20 | 2.53 | 1.31 | $t$ (33) = 0.94, $p$ = .355 |
| NSM-M | | | | | |
| Body Fat | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Perceived | 13.42 | 6.25 | 10.85 | 5.47 | *t* (33) = 1.30, *p* = .204 |
| Ideal | 9.94 | 4.57 | 9.21 | 5.71 | *t* (33) = 0.42, *p* = .681 |
| Discrepancy | -3.47 | 6.30 | -1.64 | 5.89 | *t* (33) = 0.89, *p* = .382 |
| Muscularity | | | | | |
| Perceived | 15.72 | 3.76 | 16.32 | 5.45 | *t* (33) = 0.37, *p* = .713 |
| Ideal | 21.50 | 4.06 | 22.67 | 3.04 | *t* (33) = 0.52, *p* = .338 |
| Discrepancy | 5.78 | 2.53 | 6.35 | 3.74 | *t* (33) = 0.69, *p* = .609 |
| Total EDS | 57.25 | 17.23 | 70.21 | 19.46 | *t* (33) = 2.07, *p* = .047 |
| Withdrawal Effects | 9.44 | 4.63 | 11.11 | 4.04 | *t* (33) = 1.14, *p* = .263 |
| Continuance | 7.06 | 4.12 | 7.68 | 4.06 | *t* (33) = 0.45, *p* = .657 |
| Tolerance | 11.38 | 3.81 | 11.89 | 3.77 | *t* (33) = 0.40, *p* = .689 |
| Lack of Control | 6.63 | 3.57 | 9.05 | 3.76 | *t* (33) = 1.95, *p* = .060 |
| Reduction in Other Activities | 5.81 | 3.43 | 8.16 | 3.18 | *t* (33) = 2.10, *p* = .044 |
| Time | 9.56 | 2.76 | 12.11 | 3.65 | *t* (33) = 2.29, *p* = .029 |
| Intention Effects | 7.38 | 3.54 | 10.21 | 3.97 | *t* (33) = 2.21, *p* = .034 |

### Women

For women, differences were found between groups across EDI-3 (Garner, 2004) subscales, with High risk ED group reporting significantly higher levels of ED symptoms across the following EDI-3 subscales: Drive for Thinness (*t* (32) = 2.24, *p* = .032), Body Dissatisfaction (*t* (32) = 2.14, *p* = .040, Low Self-Esteem (*t* (32) = 2.64, *p* = .012), Personal Alienation (*t*(32) = 3.26, *p* = .003), Emotional Dysregulation (*t* (32) = 3.55, *p* = .001), Perfectionism (*t* (32) = 2.37, *p* = .024), and Asceticism (*t*(32) = 3.34, *p* = .002), compared to Low risk ED group. The High risk ED group reported significantly greater levels of self-objectification (McKinley & Hyde, 1996) (OBCS Surveillance (*t* (32) = 2.45, *p* = .020), and objectification of others (OOBCS Surveillance (*t* (32) = 2.37, *p* = .024). The High risk ED group also reported more shame towards their own body (OBCS Body Shame (*t* (32) = 2.65, *p* = .012)) than the Low risk ED group, but there were no group differences in shame toward others' bodies (OOBCS Body Shame (*t* (32) = 1.47, *p* = .150)). Finally, while there were no differences between groups for control beliefs regarding one's own body shape (OBCS Control (*t* (32) = 1.78, *p* = .084)), the High risk ED group had significantly lower control beliefs regarding others' body shape than the Low risk ED control group (OOBCS Control (*t* (32) = 2.63, *p* = .013). Results from the BICI (Littleton et al., 2005) showed that the High risk ED group exhibited significantly more dysmorphic concerns than the Low risk ED group (*t* (32) = 2.38, *p* = .023). Mean scores for both groups on the EDI-3, OBCS and OOBCS subscales, and the BICI, are reported in Table 3.

Table 3 Mean scores and standard deviations for High risk ED women and Low risk ED women across measured variables.

| Measures | High risk ED women (*n* = 22) | | Low risk ED women (*n*=12) | | T-test results |
|---|---|---|---|---|---|
| | Mean | *SD* | Mean | *SD* | |
| EDI-3 | | | | | |
| Drive for Thinness | 8.05 | 7.15 | 13.92 | 7.61 | *t* (32) = 2.24, *p* = .032 |
| Bulimia | 5.45 | 5.29 | 8.67 | 8.54 | *t* (32) = 1.36, *p* = .184 |
| Body Dissatisfaction | 13.09 | 10.00 | 21.33 | 12.05 | *t* (32) = 2.14, *p* = .040 |
| Low Self-Esteem | 4.18 | 5.01 | 9.00 | 5.12 | *t* (32) = 2.64, *p* = .012 |
| Personal Alienation | 4.05 | 3.89 | 9.25 | 5.38 | *t* (32) = 3.26, *p* = .003 |
| Interpersonal Insecurity | 5.23 | 5.10 | 8.75 | 6.52 | *t* (32) = 1.74, *p* = .091 |
| Interpersonal Alienation | 5.27 | 4.22 | 9.00 | 6.63 | *t* (32) = 2.01, *p* = .053 |
| Interoceptive Deficits | 7.36 | 7.05 | 11.17 | 9.51 | *t* (32) = 1.33, *p* = .194 |
| Emotional Dysregulation | 4.45 | 3.71 | 11.42 | 7.78 | *t* (32) = 3.55, *p* = .001 |
| Perfectionism | 10.55 | 5.85 | 15.25 | 4.85 | *t* (32) = 2.37, *p* = .024 |
| Asceticism | 4.86 | 3.60 | 10.00 | 5.34 | *t* (32) = 3.34, *p* = .002 |
| Maturity Fears | 8.77 | 6.52 | 6.75 | 4.18 | *t* (32) = 0.97, *p* = .340 |
| OBCS | | | | | |
| Surveillance | 34.59 | 8.65 | 42.75 | 10.43 | *t* (32) = 2.45, *p* = .020 |

| | | | | | |
|---|---|---|---|---|---|
| Body Shame | 27.27 | 9.14 | 35.58 | 7.91 | *t* (32) = 2.65, *p* = .012 |
| Control | 39.41 | 9.16 | 33.33 | 10.14 | *t* (32) = 1.78, *p* = .084 |
| OOBCS | | | | | |
| Surveillance | 28.41 | 8.94 | 35.50 | 7.04 | *t* (32) = 2.37, *p* = .024 |
| Body Shame | 18.64 | 6.31 | 22.50 | 8.90 | *t* (32) = 1.47, *p* = .150 |
| Control | 39.73 | 7.97 | 32.25 | 7.81 | *t* (32) = 2.63, *p* = .013 |
| Total BICI | 51.95 | 16.13 | 65.92 | 16.71 | *t* (32) = 2.38, *p* = .023 |

Questionnaire results were largely in expected directions, with high risk groups showing greater levels of body image / dysmorphic concern and associated feelings and behaviours.

## Body puzzle task performance

A separate group of 155 participants (43 male, 103 female, 9 other, age: *M* = 24.90, *SD* = 7.96) were recruited via the University of Essex SONA system to rate how similar the images created in the body puzzle task were to the original image on a visual analogue scale from 0 (not at all similar in arrangement) to 100 (extremely similar in arrangement) scale. For this, the images created by participants in the body puzzle task were scanned, digitised, and presented to the separate group of raters on a computer screen. Raters were able to cross-reference the images to a digitised copy of the original, intact images (as initially shown to body puzzle task participants) (see Figure 9). Raters were shown the two (male and female) pairs of complete and recreated images made by each participant one after the other, with recreated images and body gender orders counterbalanced between raters. Ratings from the 126 created images were gathered from 62 body puzzle task participants, while the remaining 7 participants completed an online version of the body puzzle separately and one participant withdrew from the study due to not feeling well.

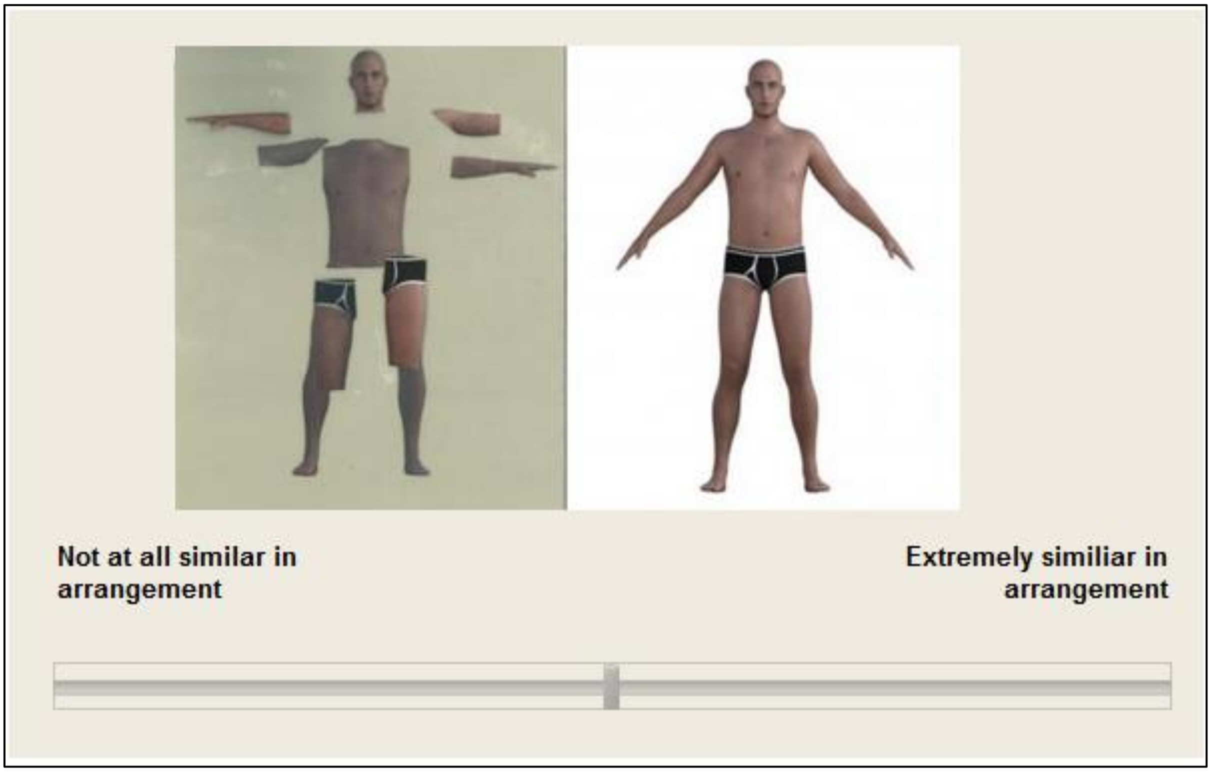



Figure 9. Example rating task. Left: scanned digitised images from puzzle task. Right: original image digitised for cross comparison. Both scanned images and original images were presented together.

All 155 participants' ratings were averaged for each body gender and for each body puzzle task participant (see Table 4). On average, male puzzles were rated as more similar to the original than female puzzles for low risk groups, and female puzzles were rated as more similar to the original than male puzzles for high risk groups.

Ratings were subject to a mixed-measures analysis of variance (ANOVA) with body puzzle rating (male rating, female rating) as the within-subject factor, and risk group (low risk, high-risk) and participant gender (male, female) as the between-subject factors. Follow-up comparisons of the estimated marginal means were Bonferroni-corrected. Greenhouse–Geisser adjustments to degrees of freedom were applied where necessary.

ANOVA revealed no significant within-subjects effects of body puzzle rating ($F$ (1, 58) = .293, $p$ =.590, $\eta_p^2$ = .005). ANOVA revealed no significant between-subjects effects of participant gender ($F$ (1, 58) = .319, $p$ =.574, $\eta_p^2$ = .005), risk group ($F$ (1, 58) <.001, $p$ =.991, $\eta_p^2$ < .001), or their interaction ($F$ (1, 58) = 2.10, $p$ =.153, $\eta_p^2$ = .035). There was a significant interaction between body puzzle rating and risk group ($F$ (1, 58) = 8.02, $p$ =.006, $\eta_p^2$ = .121), where follow-up comparisons revealed that there was a significant difference in average ratings to male body puzzles as compared to female body puzzles from low risk groups only (39.35% vs. 36.00%).

Table 4 Mean similarity ratings given to male and female body puzzles from low and high risk groups. Note that data points are collapsed for male and female participants in low and high risk groups.

| | | Male Puzzle | | Female Puzzle | |
|---|---|---|---|---|---|
| Group | *n* | *M* | *SE* | *M* | *SE* |
| Low Risk | 36 | 39.35 | 1.86 | 36.00 | 1.74 |
| High Risk | 26 | 36.51 | 2.02 | 38.78 | 2.05 |

## Experiment 1: Passive viewing detection task performance

## Planned Analysis

For the passive viewing detection task, male participants' mean correct response time was 476 ms ($SD$ = 65.12), with a mean accuracy of 99.4 % ($SD$ = 2.13). For females, mean correct response time was 510 ms ($SD$ = 58.08), with a mean accuracy of 99.1 % ($SD$ =1.61). Therefore, based on the task response accuracy, it can be inferred that participants did attend to the stimuli for the whole task duration.

## Experiment 1: Passive viewing task ERP analyses

## Planned Analysis

N170 data were subjected to a mixed-measures ANOVA with stimulus gender (male, female), desirability (desirable, undesirable), and hemisphere (left, right) as the within-subject factors, and participant risk group (low risk, high-risk) and participant gender (male, female) as the between-subject factors.

For the passive viewing task, it was found that female bodies elicit a larger N170 than male bodies in all participants ($F$ (1, 65) = 9.59, $p$ =.003, $\eta_p^2$ = 0.13; see Figure 10). This is similar to Groves et al.'s (2017) findings for N170 and VPP amplitudes and extends their findings to show that this is not only true for female participants. Enhanced responses to female bodies cannot be explained by low-level stimulus characteristics like luminosity but may be explained by female bodies drawing more attention from all participants. There was also a 4-way interaction with participant risk group, participant gender and desirability of the stimulus body ($F$ (1, 65) = 4.08, $p$ =.048, $\eta_p^2$ = .059). Pairwise comparisons of the estimated marginal means at each level of participant risk group, participant gender and desirability show that there were gender-sensitive N170 differences in high-risk women for more desirable bodies only (see Figure 10 D; see Figure 11). This replicates the gender-sensitive N170/VPP effects first shown by Groves et al. (2017) and suggests that enhanced processing of female relative to male bodies at

N170 is in fact limited to high risk women observing more desirable body types. No comparable or reverse gender effects were seen in high risk men.


Figure 10. ERP waveforms from right hemisphere cluster showing N170. Note that A and B are male participants, C and D are female participants. A and C are low-risk groups, B and D are high-risk groups. Zero indicates body stimulus onset. Shaded window indicates the approximate window of N170 analyses.

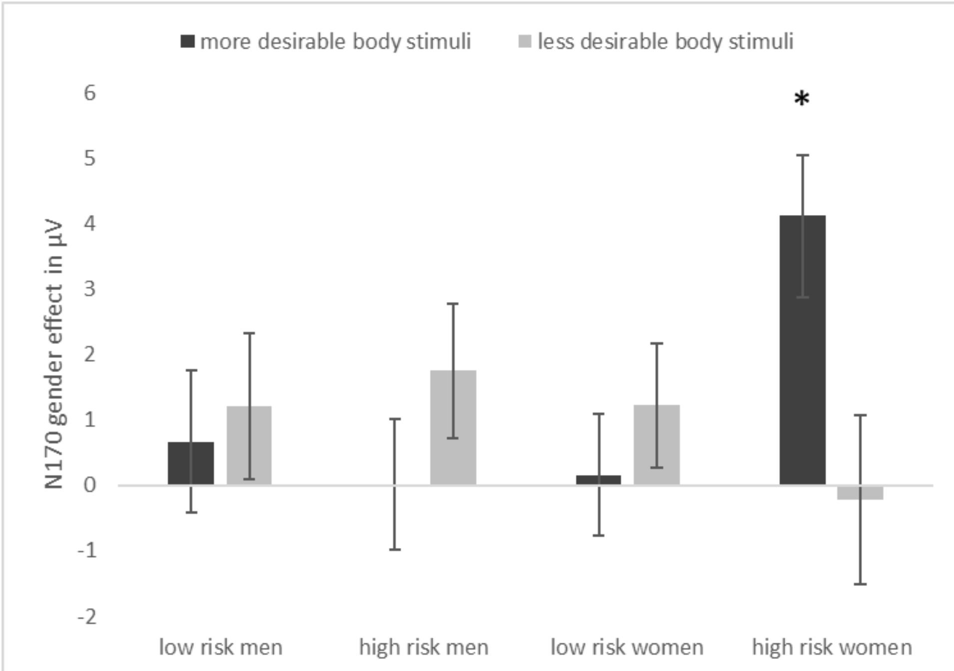



Figure 11. Gender-sensitive N170 effects split by group (low risk men; high risk men; low risk women; and high risk women) to more desirable body stimuli (dark grey bars) and less desirable body stimuli (light grey bars). Note that positive values indicate larger N170 components to female than male body stimuli. Asterisks indicate significant stimulus gender differences.

Source localisations on the 130-180 ms window of the difference waveform representing the desirability differences in gender effects (differences waves of gender effects (ERPs to female vs. male bodies) for more vs. less desirable bodies) were done using LORETA in BrainVision Analyzer 2 (Version 2.2.0, Brain Products GmbH, Gilching, Germany), separately for each participant gender and risk group (see Figure 12). The largest current source density for the desirability differences in gender effects in low-risk men was seen in left temporal cortex (BA 21; middle temporal gyrus) and that for the low-risk women was seen in right superior frontal cortex (BA 6). The strongest neural source of high-risk women's desirability differences in gender effects was seen in right occipitotemporal cortex (BA 37; fusiform gyrus), which strongly suggests the mandatory involvement of the Fusiform Body Area (FBA) in this group during the passive observation of others' bodies. While high-risk men (and low-risk women) also showed some neural sources in this same region (see Figure 12), the strongest source for their desirability differences in gender effects was in anterior prefrontal cortex (BA 10), a region involved in memory processes, mentalising and multiple task coordination (Gilbert, Spengler et al., 2006). In other words, desirability differences in gender effects were source-localised to right-lateralised cortical regions specialised for the analysis of the human body form only in our high-risk women.

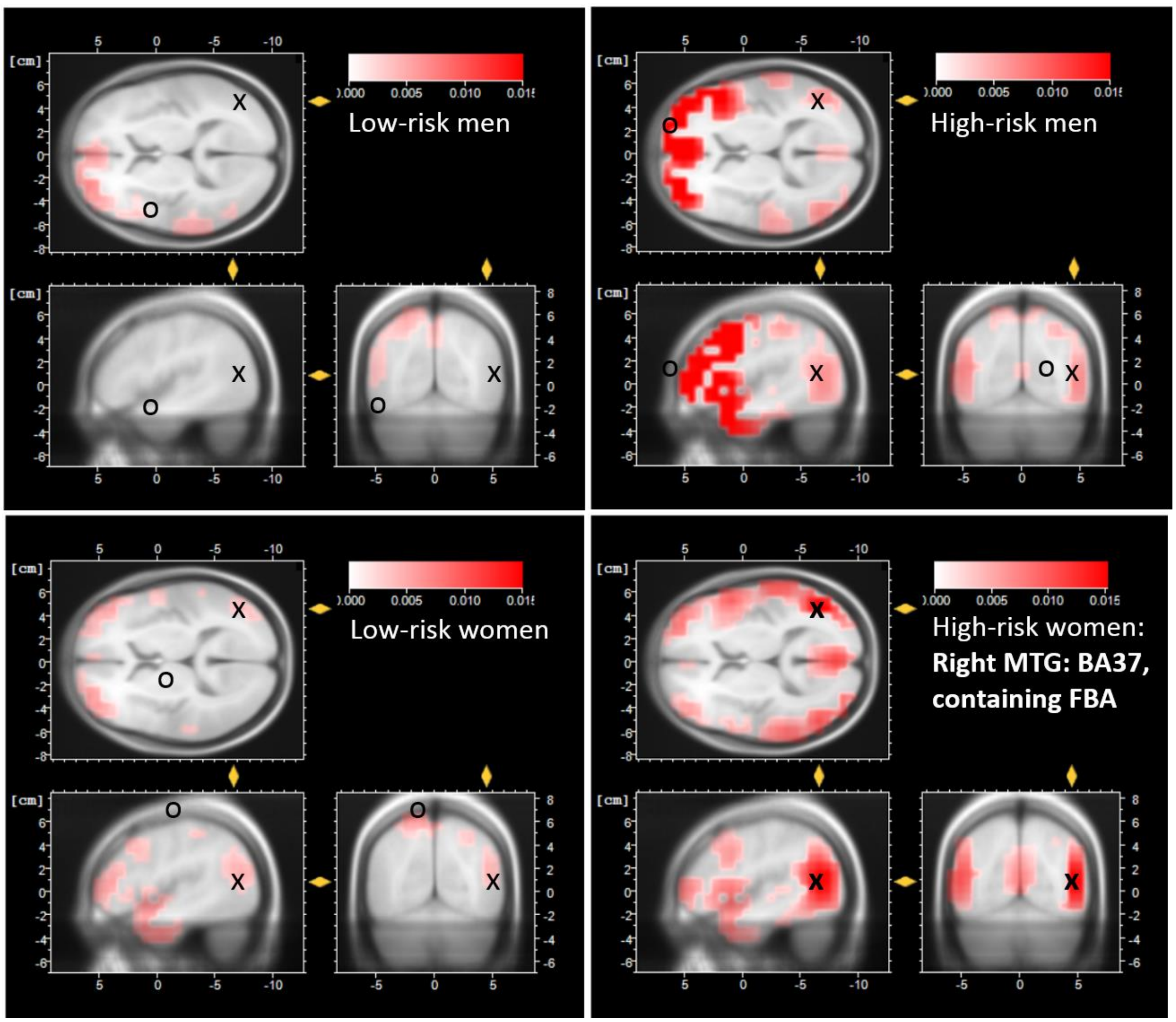



Figure 12. Source maps for desirability differences in gender effects (difference waves of gender effects (ERPs to female vs. male bodies) for more vs. less desirable bodies. Note that density

scale and coronal, sagittal and transverse slices are anchored to those identified as the best match in high-risk women in all other groups. x indicates the strongest source identified in high-risk women. o indicates the strongest source of the difference wave within the 130-180ms window for each of the other groups.

LPP (400-1000ms) data were subjected to a mixed-measures ANOVA with stimulus gender (male, female); desirability (desirable, undesirable), and hemisphere (left, right) as the within-subject factors, and participant risk group (low risk, high-risk) and participant gender (male, female) as the between-subject factors.

Female bodies also elicited a larger LPP than male bodies in all participants – there was a main effect of stimulus gender ($F$ (1, 65) = 6.14, $p$ =.016, $\eta_p^2$ = 0.09; see Figure 13). A gender-sensitive effect at LPP has not been reported before (e.g., Groves et al., 2017). The effect of stimulus gender interacted with participant gender ($F$ (1, 65) = 6.01, $p$ =.017, $\eta_p^2$ = 0.09). Pairwise comparisons of the estimated marginal means at each level of participant gender showed that the overall gender differences at LPP were entirely driven by our female participant groups. There was no statistically significant gender-sensitive effects within the male participants. Desirable bodies also led to a larger LPP than undesirable bodies overall ($F$ (1, 65) = 24.62, $p$ < .001, $\eta_p^2$ = .28). Finally, there was a 3-way interaction between desirability, stimulus gender and participant risk group ($F$ (1, 65) = 5.19, $p$ = .026, $\eta_p^2$ = .07), and a 4-way interaction between desirability, stimulus gender, participant risk group and participant gender ($F$ (1, 65) = 4.61, $p$ = .036, $\eta_p^2$ = .07). Pairwise comparisons of the estimated marginal means at each level of desirability, participant risk group and participant gender again showed that the gender-sensitive effects at LPP were present only in the female participants: low-risk women show gender differences for more desirable bodies (larger LPPs for more desirable female than male bodies) while high-risk women showed gender differences for less desirable bodies (larger LPPs for less desirable female than male bodies) (see Figure 13 C and D; see Figure 14).


Figure 13. Waveforms from central / vertex cluster showing LPP. Note that A and B are male participants, C and D are female participants. A and C are low-risk groups, B and D are high-risk groups. Zero indicates body stimulus onset. Shaded window indicates the approximate window of LPP analyses.

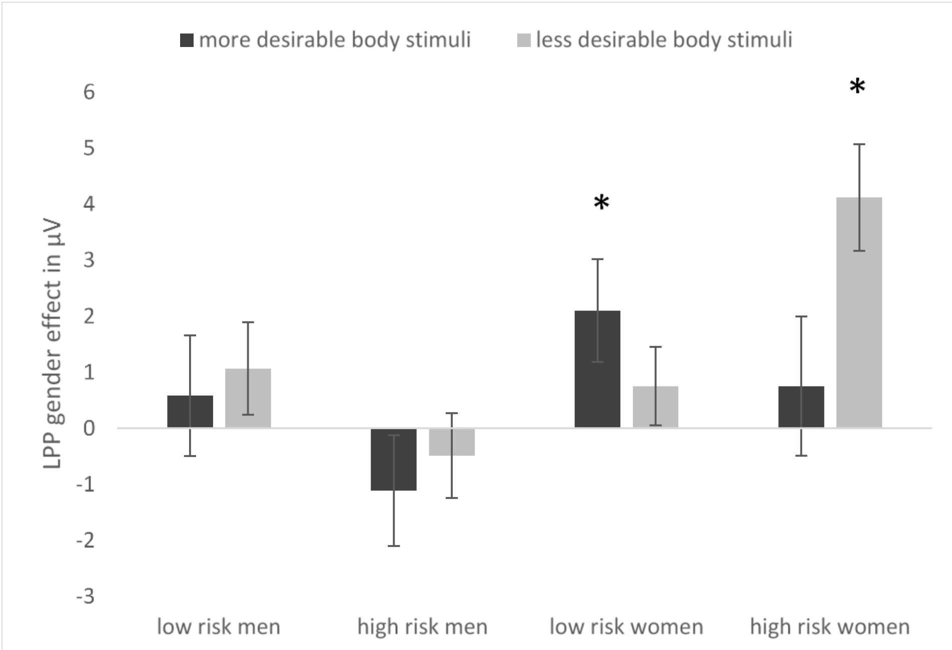



Figure 14. Gender-sensitive LPP effects split by group (low risk men; high risk men; low risk women; and high risk women) to more desirable body stimuli (dark grey bars) and less desirable body stimuli (light grey bars). Note that positive values indicate larger LPP components to female than male body stimuli. Asterisks indicate significant stimulus gender differences.

## Exploratory Analysis

Significant findings (overall gender effects at N170 and LPP; desirability differences in gender effects at N170 and LPP) were entered into correlational analyses with questionnaire measures for all male and all female participants. The overall gender effects at N170 and LPP (calculated as waveforms to female body stimuli subtracted from waveforms to male body stimuli for N170 and as waveforms to male body stimuli subtracted from waveforms to female body stimuli for LPP) did not correlate with any body image measures in men and in women, except for a positive correlation of the N170 gender effect with EDI-3 personal alienation in women (non-parametric correlation as EDI personal alienation scores were not normally distributed: Spearman's *r* = .341, *p* =.049). Those women with larger N170 gender-sensitive effects had higher scores on EDI personal alienation subscale. The desirability differences in gender effects (calculated as gender effects in response to less desirable bodies subtracted from gender effects in response to more desirable bodies) did not correlate with any body image measures in men for either N170 or LPP waveforms. In women, the N170 desirability differences in gender effects correlated negatively with OOBCS control (parametric correlation: Pearson's *r* = -.350, *p* =.042). Those women with stronger N170 gender differences for more desirable than for less desirable bodies (i.e., differences as seen in our high-risk women; see Figure 11) had less strong beliefs that others have control over their appearance. Those women with stronger LPP gender differences for less desirable than for more desirable bodies (i.e., differences as seen in our high-risk women; see Figure 15) had higher drive for thinness, body dissatisfaction, body shame, and viewed their own and others' bodies more from an outside observer's perspective. In women, the LPP desirability differences in gender effects correlated negatively with EDI drive for thinness (Pearson's *r* = -.391, *p* =.022), EDI body dissatisfaction (Pearson's *r* = -.515, *p* = .002), OBCS surveillance (Pearson's *r* = -.437, *p* =.010), OBCS body shame (Pearson's *r* = -.366, *p* =.033) and OOBCS surveillance (Pearson's *r* = -.431, *p* =.011) (see Figure 16).

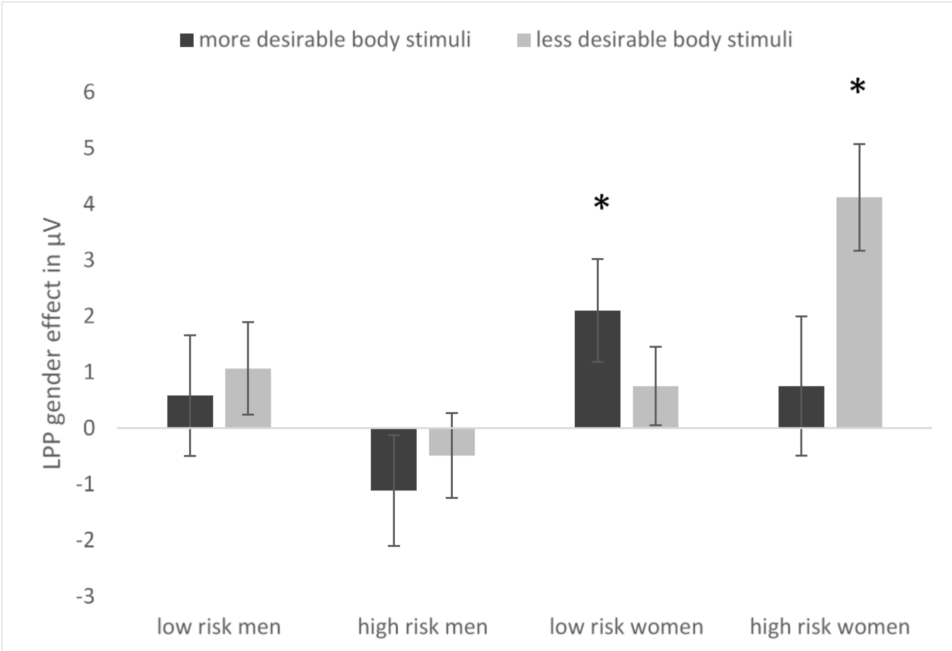



Figure 15. Grand average LPP amplitudes in microvolts split by group (low risk men; high risk men; low risk women; and high risk women) to more desirable body stimuli (dark grey bars) and less desirable body stimuli (light grey bars). Note that positive values indicate larger LPP components to female than male body stimuli. Asterisks indicate significant stimulus gender differences.

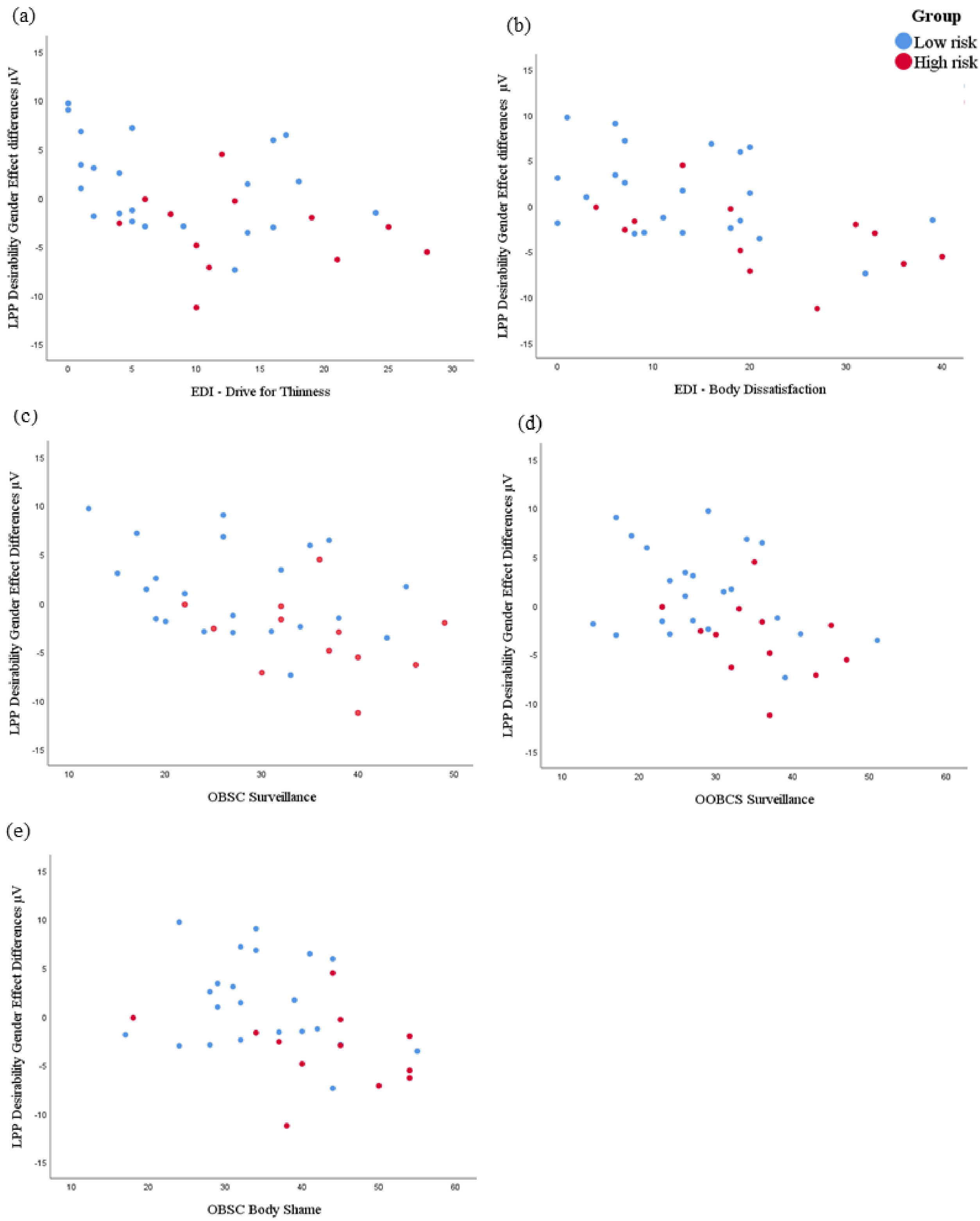



Figure 16. Female LPP desirability differences in gender effects correlated with (a) EDI drive for Thinness; (b) EDI drive for dissatisfaction, (c) OBSC Surveillance; (d) OBSC Shame; and (e) OOBSC Surveillance.

In sum, high-risk women showed gender-sensitive ERP effects for more desirable bodies, which may reflect upward social comparisons, at early stages in body processing (N170), which was source localised to right occipitotemporal cortex (likely FBA). Low-risk women only show such gender-sensitive effects at later processing stages (LPP). High-risk women further have a late (LPP) gender-sensitive effect for less desirable bodies that may possibly index 'fear of fatness', which is characteristic of women with eating disorders. No convincing gender-sensitive effects were seen in male participants, nor did any such effects systematically relate to questionnaire responses assessing male body image. In addition, we also observed main effects of desirability, such that more desirable bodies elicited larger LPP waves than less desirable bodies overall, indicating aesthetic processing differences for bodies in this time range.

## Experiment 2: Inversion task response times and accuracy

## Planned Analysis

To determine inversion task performance the proportion of correct responses (accuracy) and mean RTs to correct responses were calculated for each stimulus and orientation in each participant (as in Feusner, Moller, et al., 2010; Mundy & Sadusky, 2014; Urgesi et al., 2014). Trials with an RT higher than 5,000 ms were identified and discarded (as in Urgesi et al., 2014). Both RTs and accuracy were then averaged across participants and subjected to separate mixed factorial ANOVA with orientation (upright, inverted), stimulus gender (male, female), and hemisphere (left, right) as the within-subjects factors, and participant risk group (low risk, high risk) and participant gender (male, female) as the between-subject factors. Follow-up comparisons of the estimated marginal means were Bonferroni-corrected. Greenhouse–Geisser adjustments to degrees of freedom were applied where necessary. Where applicable, t-tests are reported unsigned. Note that Inverse efficiency (Townsend and Ashby, 1978, 1983), calculated by dividing the mean RT by the mean proportion correct, could not be used in this study because it is thought to be reliable only with mean correct responses above .90, while in this task correct responses averaged .71 (Bruyer and Brysbaert, 2011). Therefore, RTs and accuracy data were analysed and are reported separately. Tables 5 and 6 show means for RTs and accuracy across conditions and groups.

Table 5 Mean RTs (SEMs) in ms across stimulus conditions and participant groups.

| Group | Male body stimuli | | Female body stimuli | |
|---|---|---|---|---|
| | Upright | Inverted | Upright | Inverted |
| Low-risk men | 963 (77) | 1053 (88) | 919 (72) | 1005 (72) |
| High-risk men | 1106 (70) | 1241 (81) | 1053 (66) | 1061 (66) |
| Low-risk women | 1190 (65) | 1355 (75) | 1142 (61) | 1214 (62) |
| High-risk women | 1161 (89) | 1238 (102) | 1057 (83) | 1137 (83) |

Table 6 Mean accuracy (SEMs) in % across stimulus conditions and participant groups.

| Group | Male body stimuli | | Female body stimuli | |
|---|---|---|---|---|
| | Upright | Inverted | Upright | Inverted |
| Low-risk men | 73.8 (1.9) | 59.9 (1.5) | 79.0 (1.5) | 72.9 (1.9) |
| High-risk men | 70.4 (1.8) | 61.5 (1.4) | 78.1 (1.4) | 72.8 (1.8) |
| Low-risk women | 69.2 (1.7) | 60.6 (1.3) | 77.4 (1.3) | 73.4 (1.7) |
| High-risk women | 74.2 (2.2) | 61.1 (1.7) | 80.7 (1.7) | 74.8 (2.2) |

It is noteworthy that our high-risk men were slower to respond and had lower accuracy than low risk men, especially for same-sex body stimuli. The opposite was true for our women: high risk women were faster to respond and had higher accuracy than low risk women, especially to same-sex body stimuli. However, ANOVAs did not reveal any significant between-subject effect of participant risk group, participant gender or their interaction in RTs or accuracy.

Behavioural body inversion effects were present in RTs (longer RTs to inverted than upright body stimuli) ($F$ (1, 65) = 67.01, $p$ < .001, $\eta_p^2$ = 0.51) and accuracy (worse accuracy to inverted than upright body stimuli) ($F$ (1, 65) = 99.75, $p$ < .001, $\eta_p^2$ = 0.61). Responses were also faster and more accurate to female than male body stimuli overall (RT: $F$ (1, 65) = 39.58, $p$ < .001, $\eta_p^2$ = 0.38; accuracy: $F$ (1, 65) = 221.27, $p$ < .001, $\eta_p^2$ = 0.77). There was an interaction between orientation and stimulus gender in both RTs ($F$ (1, 65) = 4.80, $p$ =.032, $\eta_p^2$ = 0.07) and accuracy ($F$ (1, 65) = 16.63, $p$ < .001, $\eta_p^2$ = 0.20) data because male body stimuli elicited much larger BIEs than female body stimuli, although BIEs were present for both stimulus genders (see Figure 16). For RTs, this further interacted with participant risk group and participant gender ($F$ (1, 65) = 4.62, $p$ =.035, $\eta_p^2$ = 0.07). Pairwise comparisons of estimated marginal means at each level of participant risk group, participant gender and stimulus gender showed that BIEs in RTs differed across groups and conditions (see Figure 17). BIEs were larger for male than female body stimuli in high-risk men and low-risk women but appeared comparable in size in low-risk men and high-risk women. BIEs were statistically absent for female bodies in high risk men and for male bodies in high risk women, suggesting that high risk participants only show reliable BIEs for bodies of their own gender. This was only true for RTs, but not for accuracy data (see Figure 17).

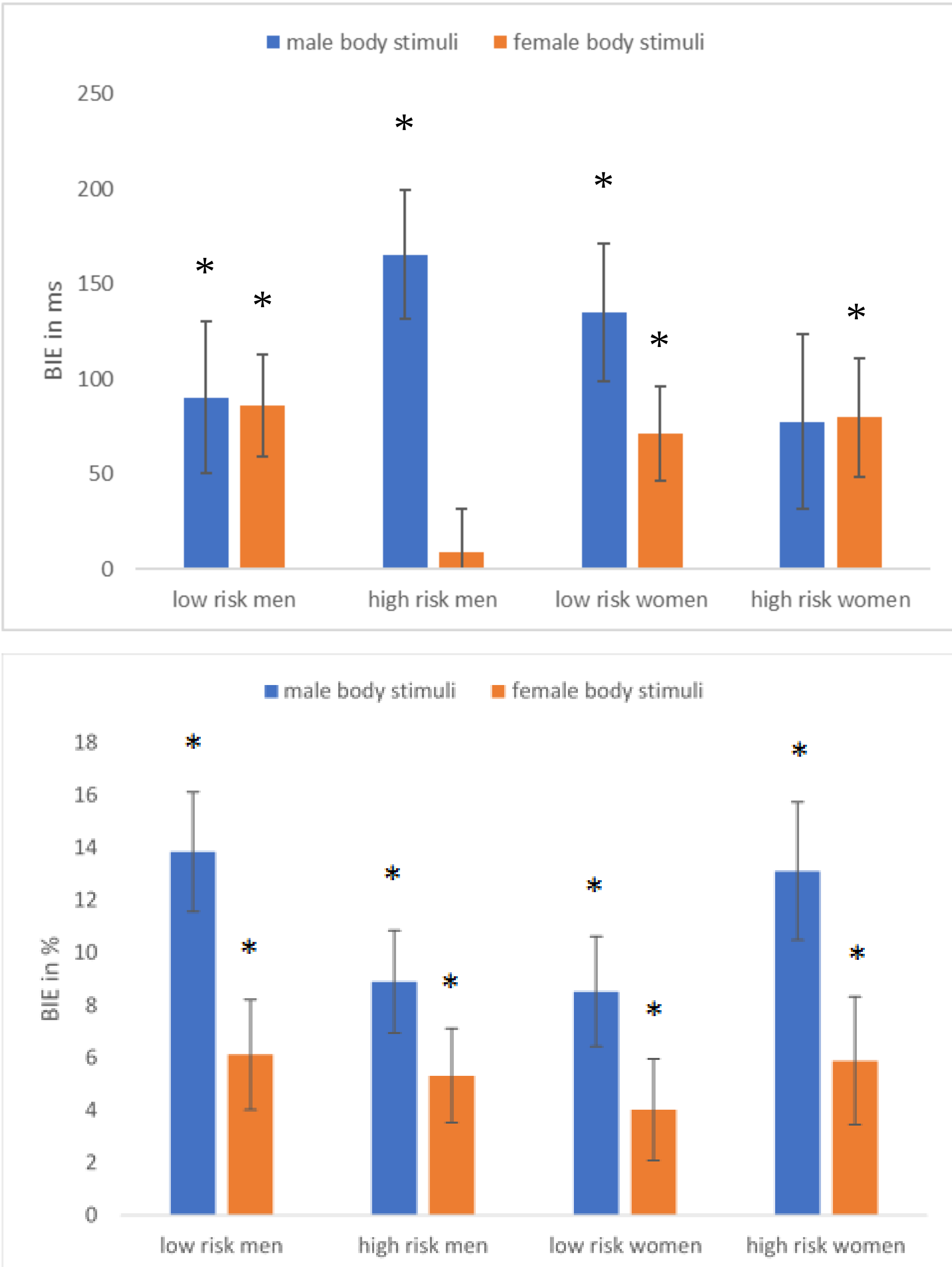



Figure 17. Top panel shows Response times (ms), bottom panel shows Accuracy (%). Error bars depict standard error of the means, and asterisks indicate significant pairwise comparisons. Note that larger positive values indicate larger BIEs (longer RTs / worse accuracy to inverted relative to upright stimuli). Asterisk means that the BIE in that condition was significant ($p$ <.05).

## Exploratory Analysis

Significant findings (overall BIEs; gender differences in BIEs) were entered into correlational analyses with questionnaire measures for all male and all female participants.

In men, BIEs in RTs (calculated as RTs to upright stimuli subtracted from RTs to inverted stimuli) did not correlate with any body image questionnaire measures. BIEs for accuracy data (calculated as accuracy to inverted stimuli subtracted from accuracy to upright stimuli) only correlated negatively with EMS total (non-parametric correlation as EMS total scores were not normally distributed: Spearman's $r$ = -.335, $p$ = .049), such that those men with smaller BIEs in accuracy (i.e., as more characteristic of our high-risk group) had higher levels of muscularity-oriented disordered eating psychopathology.

In women, BIEs in RTs correlated positively with EDI asceticism (Spearman's $r$ = .388, $p$ = .023) and OBCS surveillance (Pearson's $r$ = .366, $p$ = .036). BIEs in accuracy data correlated positively with EDI low self-esteem (non-parametric correlation as EDI scores were not normally distributed: Spearman's $r$ = .386, $p$ = .024) and EDI interpersonal insecurity (Spearman's $r$ = .380, $p$ = .027), and correlated negatively with OOBCS control (Pearson's $r$ = -.343, $p$ = .049). This suggests that women with larger BIEs in RTs (i.e., as more characteristic of our low-risk group) also have higher asceticism and view their body more like an outside observer. Women with larger BIEs in accuracy (i.e., as more characteristic of our high-risk group) also had lower self-esteem and more interpersonal insecurities as well as less strong beliefs that others have control over their own appearance.

In men, gender differences in BIEs in RTs (calculated as BIEs in RTs to female body stimuli subtracted from BIEs in RTs to male body stimuli) correlated positively with MDDI total (non-parametric correlation as gender differences in BIEs in RTs were not normally distributed: Spearman's *r* =.379, *p* =.025), FFMI discrepancy (Spearman's *r* = .411, *p* = .014), SATAQ thinness (Spearman's *r* =.441, *p* =.008), SATAQ general attractiveness (Spearman's *r* = .473, *p* = .004), SATAQ family (Spearman's *r* = .356, *p* = .036) and SATAQ media (Spearman's *r* = .422, *p* = .012). Gender differences in BIEs in accuracy data (calculated as BIEs in accuracies to female body stimuli subtracted from BIEs in accuracies to male body stimuli), however, correlated negatively with MDDI appearance intolerance (Pearson's *r* = -.462, *p* = .005), SATAQ family (Spearman's *r* = -.362, *p* = .033) and SATAQ media (Spearman's *r* = -.340, *p* = .046). This suggests that men with larger gender effects in BIEs in RTs (i.e., stronger BIEs to male than female bodies as seen in our high-risk group; see Figure 16 top panel) also had higher scores on MDDI (see Figure 18 for illustration), greater discrepancies between actual and ideal fat-free muscle mass, greater internalisation of body ideals and greater pressures to follow those ideas. Conversely, men with larger gender effects in BIEs in accuracy data (i.e., stronger BIEs to male than female bodies as more characteristic of our low-risk group; see Figure 16 bottom panel) also had lower MDDI appearance intolerance (see Figure 19 for illustration) and fewer pressures to follow body ideals.

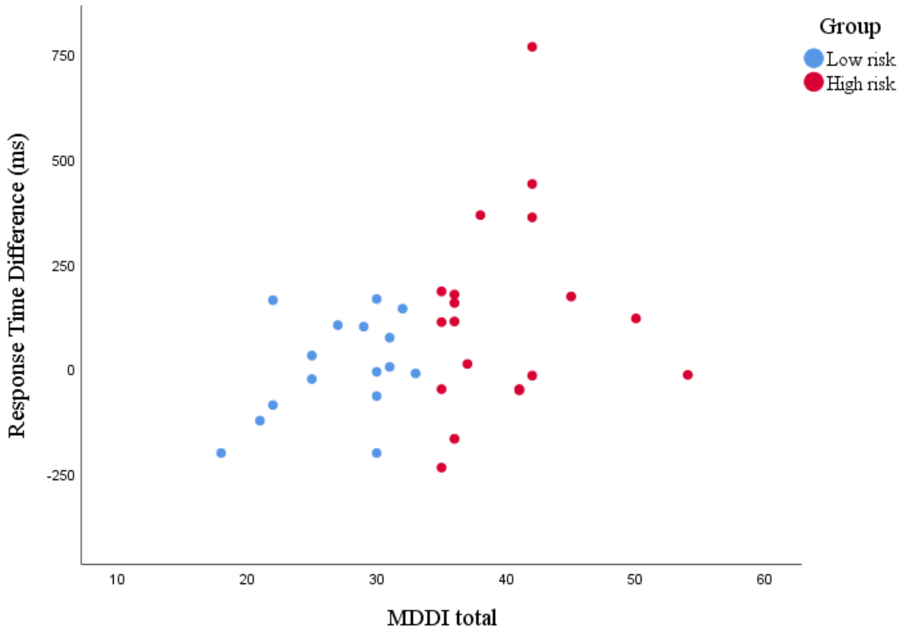



Figure 18. Gender differences in BIE response time differences correlated with MDDI total, where positive values on the MDDI total indicate greater muscle dysmorphia symptomology.

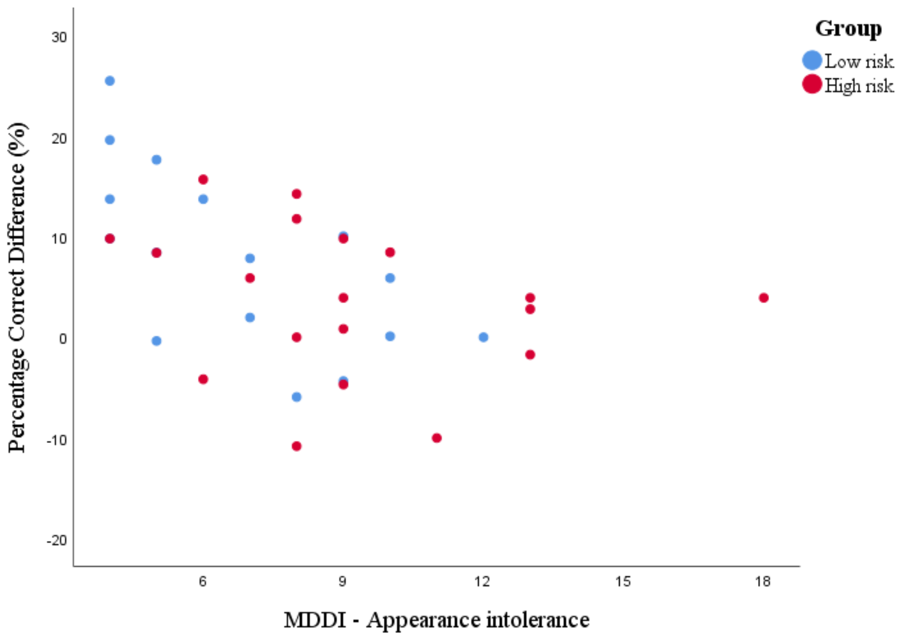



Figure 19. Gender differences in BIE accuracy differences correlated with MDDI appearance intolerance subscale, where positive values on the MDDI appearance intolerance subscale indicate greater appearance intolerance.

In women, gender differences in BIEs in RTs did not correlate with any body image questionnaire measure. Gender differences in BIEs in accuracy data correlated positively with EDI bulimia (non-parametric correlation as EDI bulimia scores were not normally distributed: Spearman's *r* =.352, *p* =.041), such that those women with larger gender effects in BIEs in accuracy data (i.e., stronger BIEs to male than female bodies as more characteristic of our high-risk group; see Figure 16 bottom panel) also had more bulimic symptoms (see Figure 20 for illustration).

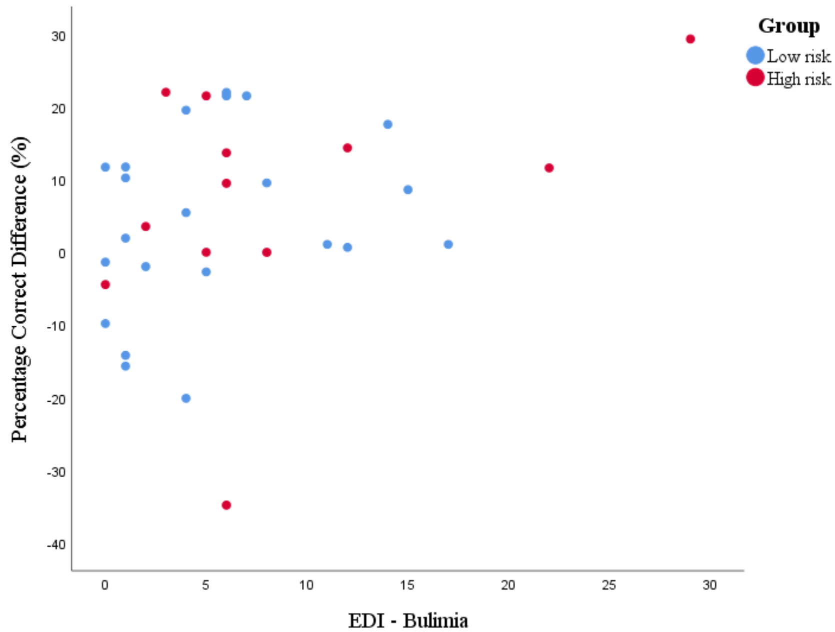



Figure 20. Gender differences in BIE accuracy differences correlated with EDI Bulimia subscale, where positive values on the EDI Bulimia subscale indicate greater bulimia symptomology.

Although the patterns of behavioural BIEs in this task were complex, it emerges that high-risk groups, and higher levels of body image symptoms typical of risk groups, are characterised by larger BIEs (rather than as hypothesised by smaller BIEs) and by larger gender effects in BIEs. Notable exceptions to this general finding were that men with higher levels of muscularity-oriented disordered eating psychopathology had smaller BIEs in accuracy and men with more MDDI appearance intolerance and greater internalisation of muscle ideals had smaller gender differences in BIEs in accuracy. This suggests that the accuracy of body discrimination (as measured in body inversion tasks) may be a reasonable marker of MD symptomology in men. Our findings also raise concerns and questions regarding the use of the body inversion task as in index of BICs in women.

## Experiment 2: Inversion task ERP analyses

## Planned Analysis

Body inversion effects were also present at the N170 (more negative mean amplitudes to inverted than upright body stimuli in the 110-160ms time window centred on the N170) ($F$ (1, 65) = 73.29, $p < .001$, $\eta_p^2 = 0.53$) (see Figure 20). The N170 BIE was larger in women than in men (interaction between orientation and participant gender: $F$ (1, 65) = 16.26, $p < .001$, $\eta_p^2 = 0.20$) (see Figure 20 top vs. bottom panel; see Figure 21). Although BIEs were somewhat larger in response to female than male body stimuli overall, this difference was not significant (interaction between orientation and stimulus gender: $F$ (1, 65) = 3.76, $p$ =.057, $\eta_p^2 = 0.06$). It is interesting to note that the opposite was seen in behavioural data overall: significantly larger BIEs to male than female body stimuli. One exception to this is our group of high-risk men, who consistently showed larger inversion effects to male than female body stimuli in both behavioural and N170 data (see Figure 21 top panel C and D; see Figure 22).

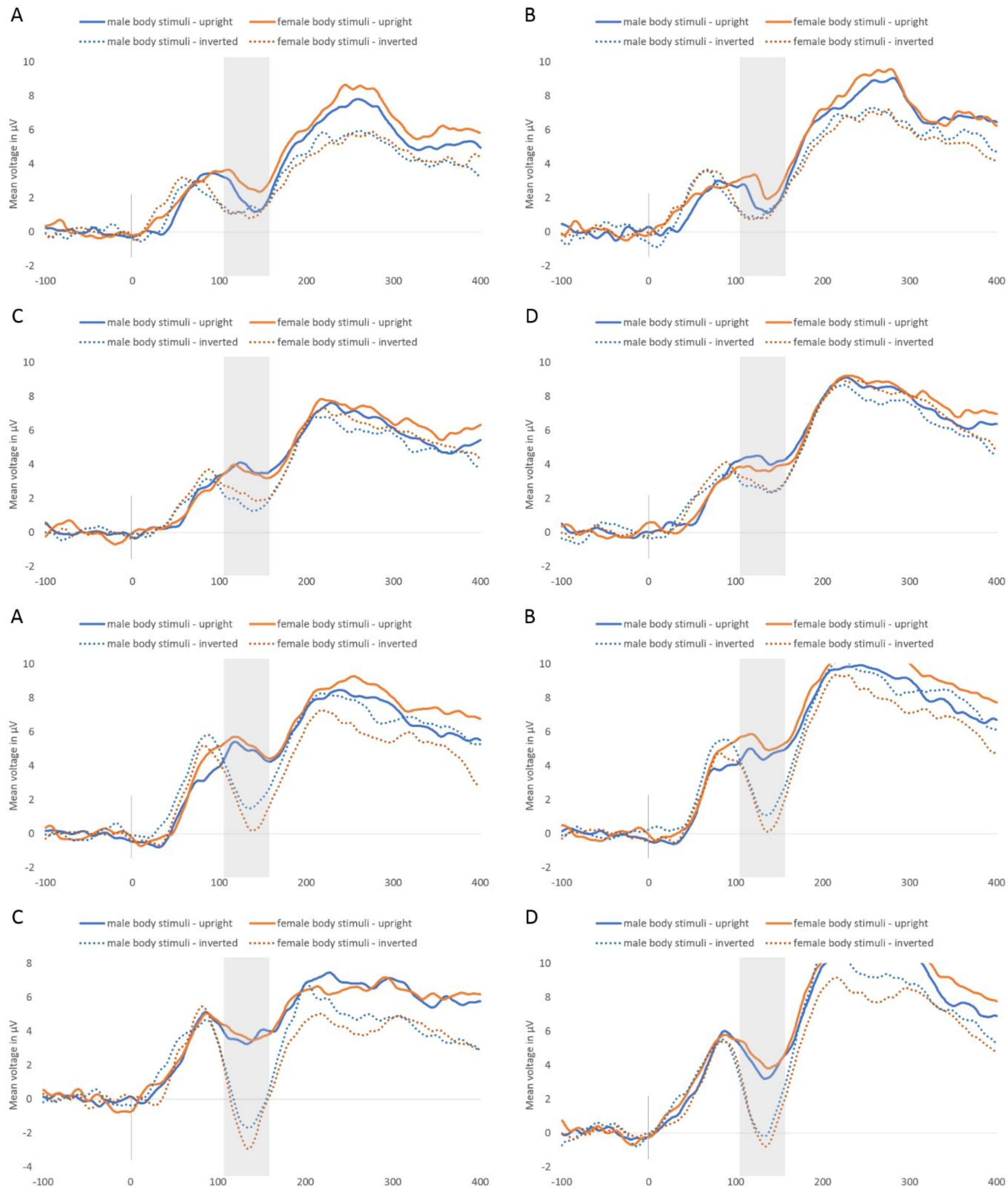



Figure 21. Waveforms from left and right hemisphere clusters showing N170 BIEs in men (top panel) and women (bottom panel). A and B are low-risk groups, C and D are high-risk groups. A and C are left-hemisphere waveforms, B and D are right-hemisphere waveforms. Zero indicates body stimulus onset. Shaded window indicates the approximate window of N170 analyses.

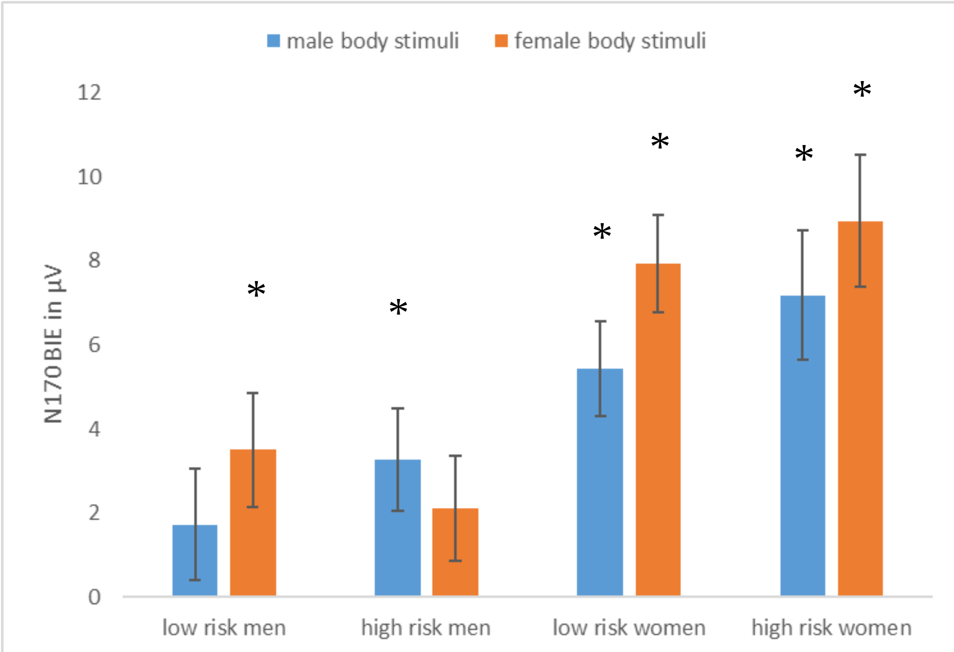



Figure 22. N170 BIEs split by group (low risk men; high risk men; low risk women; and high risk women) to male body stimuli (blue bars) and female body stimuli (orange bars). Note that larger positive values indicate larger BIEs (enlarged N170 for inverted relative to upright stimuli). Asterisk means that the BIE in that condition was significant.

Importantly, N170 BIEs interacted with participant risk group and hemisphere ($F$ (1, 65) = 4.11, $p$ = .047, $\eta_p^2$ = 0.06), such that the high-risk groups (both men and women) were marked by a relatively stronger inversion effect in left vs. right hemispheres, while the low-risk groups' BIEs were more balanced across hemispheres (see Figure 21 top and bottom C vs. D; See Figure 23).

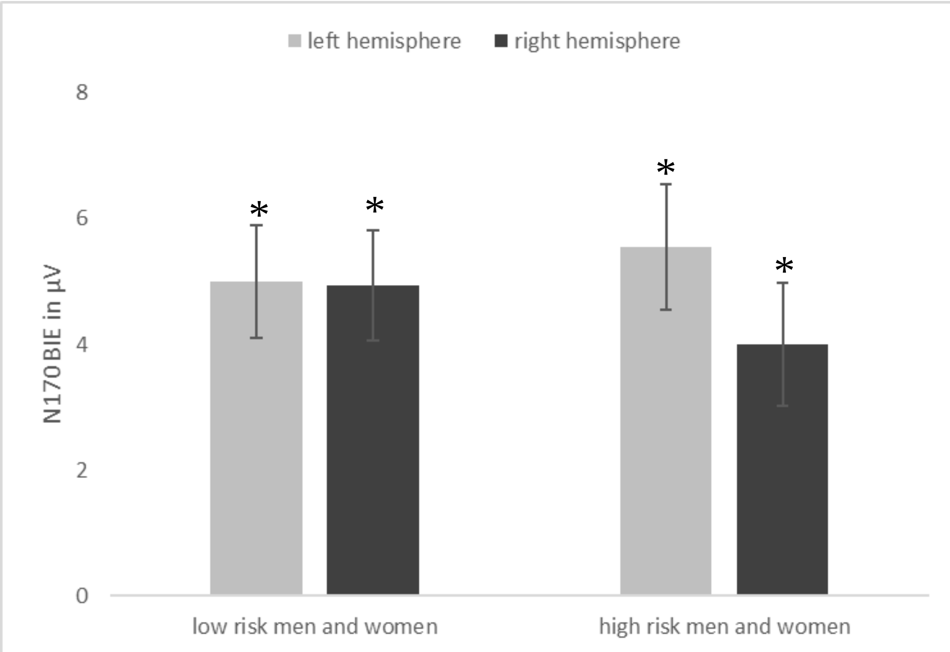



Figure 23. N170 BIEs split by participant risk group (low risk and high risk) and hemisphere (left hemisphere: light grey bars; right hemisphere: dark grey bars. Note that larger positive values indicate larger BIEs (enlarged N170 for inverted relative to upright stimuli). Asterisk means that the BIE in that condition was significant.

Source localisations on the 110-160 ms window of the difference waveforms (upright vs. inverted) were done using LORETA in BrainVision Analyzer 2 (Version 2.2.0, Brain Products GmbH, Gilching, Germany), separately for each participant gender and risk group (see Figure 23). The largest current source densities for the low-risk groups were in left (low-risk men) and right (low-risk women) medial superior parietal cortex (BA 7; precuneus), a region involved in a wide variety of highly integrated tasks such as body coordination and perspective-taking, imagery, and memory retrieval (Cavanna & Trimble, 2006). Sometimes seen as part of the default mode network, it is also a region that is highly active at rest, which suggests that low-risk participants were engaged in some self-related processing during the visual discrimination of others' bodies. For high-risk groups, however, current source densities differed. The strongest neural source of high-risk women's BIEs was seen in left occipitotemporal cortex (BA 37; fusiform gyrus), which again suggests the mandatory involvement of the Fusiform Body Area (FBA) in this group during the visual discrimination of others' bodies. While high-risk men (and indeed all groups) showed some neural sources in this same region (see Figure 24), the strongest source for their BIEs was not in left occipitotemporal cortex, but again in anterior prefrontal cortex (BA 10), a region involved in memory processes, mentalising and multiple task coordination (Gilbert, Spengler et al., 2006). Therefore, BIEs were source-localised to left-lateralised cortical regions specialised for the analysis of the human body form only in our high-risk women.

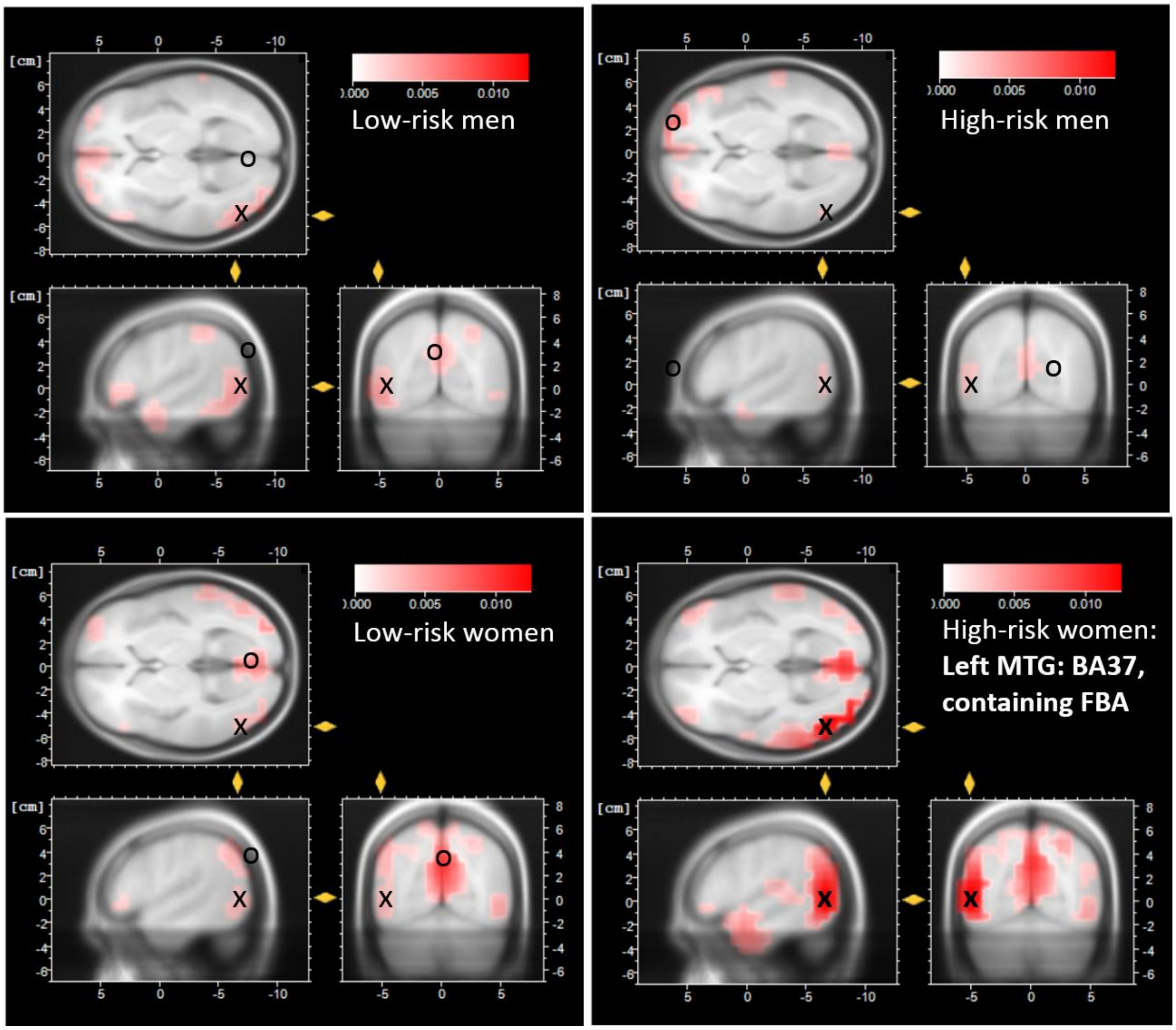



Figure 24. Source maps for BIEs (differences wave of upright vs. inverted bodies). Note that density scale and coronal, sagittal and transverse slices are anchored to those identified as the best match in high-risk women in all other groups. x indicates the strongest source identified in high-risk women. o indicates the strongest source of the difference wave within the 110-160ms window for each of the other groups.

## Exploratory Analysis

Significant findings (overall BIE; hemispheric differences in BIE) were entered into correlational analyses with questionnaire measures for all male and all female participants.

The overall body inversion effect (calculated as waveforms to inverted stimuli subtracted from waveforms to upright stimuli) did not correlate with any body image questionnaire measures for both male and female participant groups.

In men, the hemispheric differences in inversion effect (calculated as BIEs in right hemisphere waveforms subtracted from BIEs in left hemisphere waveforms) did not correlate with any questionnaire measures.

In women, hemispheric differences in inversion effect correlated positively with EDI-3 low self-esteem (non-parametric correlation as some EDI-3 scores were not normally distributed: Spearman's $r$ =.409, $p$ = .016), EDI-3 personal alienation (Spearman's $r$ = .510, $p$ = .002), EDI-3 interoceptive deficits (Spearman's $r$ = .414, $p$ = .015), EDI-3 emotional dysregulation (Pearson's $r$ = .521, $p$ = .002), EDI-3 perfectionism (Pearson's $r$ = .437, $p$ = .010), EDI-3 asceticism (Spearman's $r$ = .542, $p$ < .001), EDI-3 maturity fears (Spearman's $r$ = .413, $p$ = .015), and OBCS surveillance (Pearson's $r$ = .354, $p$ = .040) (see Figure 25 for illustration). This suggests that women with more hemispheric imbalances in BIE (i.e., smaller BIEs in right hemispheres and larger BIEs in left hemispheres) also report more eating disorder symptoms and a greater tendency to view their own body from an external perspective.

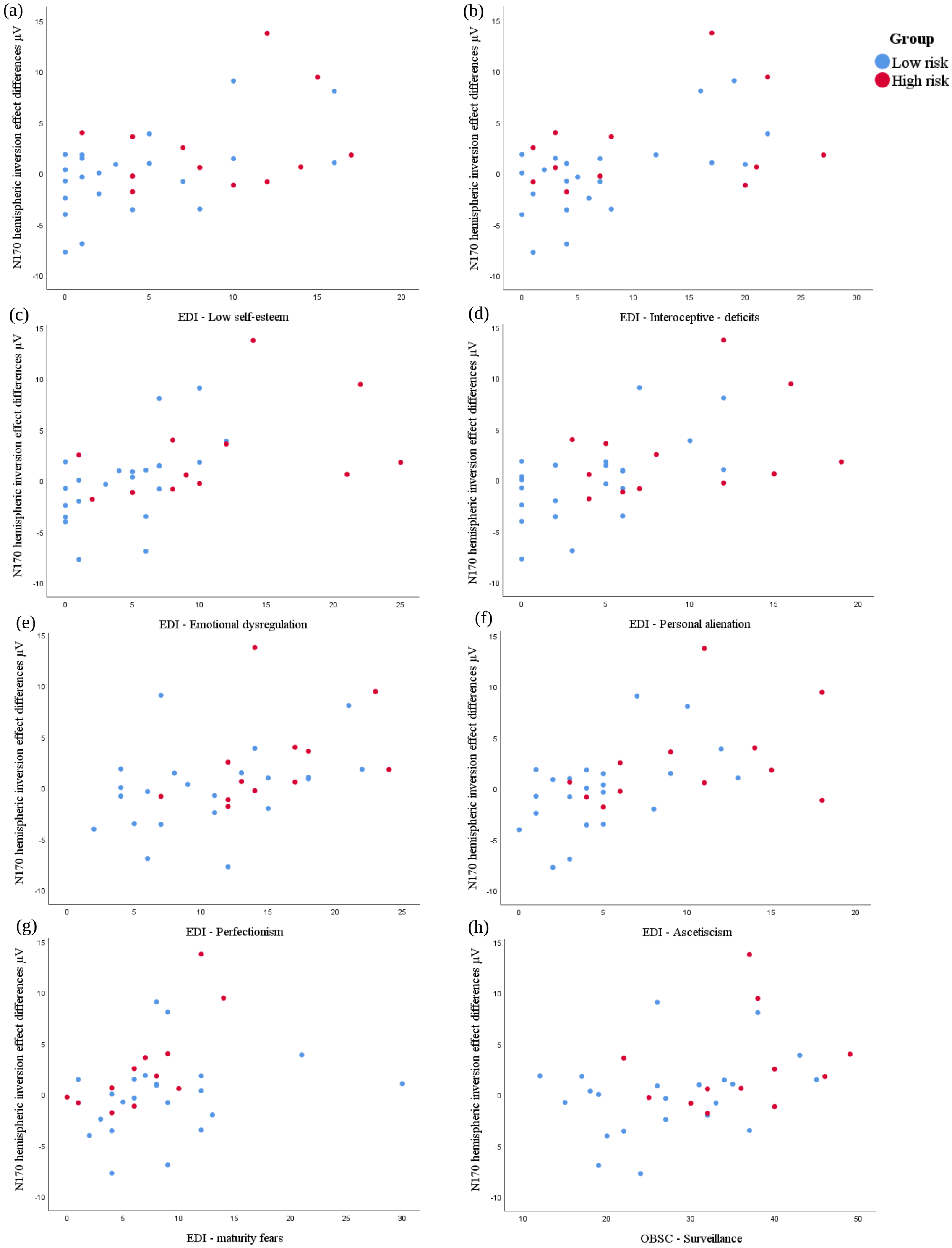



Figure 25. Female N170 hemispheric inversion effect differences correlated with (a) EDI-3 low self-esteem; (b) EDI-3 personal alienation, (c) EDI-3 interoceptive deficits; (d) EDI-3 emotional dysregulation; (e) EDI-3 perfectionism; (f) EDI-3 asceticism; (g) EDI-3 maturity fears; and (h) OBCS surveillance.

# Discussion

To the best of our knowledge, this is a novel study investigating the temporal dynamics of body-sensitive and gender-sensitive visual processing in both male and female observers at low and high risk of body image disturbances, with the aim of identifying potential biomarkers related to disorders marked by body image disturbances, including MD, BDD and EDs. In Experiment 1 (passive viewing of bodies), we expected that both High risk groups would, compared to Low risk groups, show larger N170 and LPP responses for same-gender than opposite-gender and for more desirable bodies than less desirable bodies. In Experiment 2 (body inversion task), we expected that both High risk groups would, compared to Low risk groups, show reduced body inversion effects both in behaviour (RTs and accuracy) and ERPs (N170). We hypothesised that such evidence of amplified perceptual and emotional processing for certain bodies, as well as reduced configural processing, could be markers of body image disturbance (see Groves et al., 2017, 2020) that also extend to male populations. To support this link, we also tested whether self-reported body image disturbance and related behavioural symptoms (measured through questionnaires) across all male and all female participants systematically correlated with behavioural and ERP markers of body processing.

## Behavioural and ERP markers of body perception differ between risk groups

### Planned analysis

In Experiment 1, we found that female bodies elicited a larger N170 than male bodies in all participants. This extends Groves et al.'s (2017) findings for gender-sensitive N170 and VPP amplitudes from female-only to both female and male participants and is in line with findings by Hietanen and Nummenmaa (Alho, Salminen, Sams, Hietanen, & Nummenmaa, 2015; Hietanen & Nummenmaa, 2011). However, closer inspection showed that enhanced processing of female relative to male bodies at N170 was in fact driven by and limited to High risk women observing more desirable body types. This gender-sensitive effect was localisable to body-selective regions in right occipitotemporal cortex (FBA), suggesting mandatory involvement of these regions during the passive viewing of (desirable) bodies. No comparable or reverse gender effects were seen in High risk men, or indeed in any of the other groups in follow-up pairwise comparisons. This is unlike Hietanen & Nummenmaa (2011), who showed larger N170 to female than male bodies in male participants. Although high-risk men also showed some neural sources in right occipitotemporal cortex, gender-sensitive N170 differences for more vs. less desirable bodies were more strongly localised to anterior prefrontal cortex in this group. This shows some clear differences between male and female High risk groups – only female participants at risk of body image disturbance show strong and own-gender-sensitive engagement of body-selective processing during the passive viewing of (desirable) bodies, that is, even when the task is relatively undemanding with regard to body perception.

Overall, more desirable bodies elicited larger LPP waves than less desirable bodies, indicating aesthetic processing differences for bodies in this time range (see Amodio et al., 2014; Jacobsen, 2013; Gable & Harmon-Jones, 2013). We further found that gender-sensitive effects at LPP, which to the best of our knowledge have not been reported before, were present only in female participants and interacted with desirability. Low risk women had larger LPPs for more desirable female than male bodies, while High risk women had larger LPPs for less desirable female than male bodies. This may indicate that low risk women engage in the same gender-sensitive processing of bodies as High risk women, with a bias toward desirable female bodies, but do so at later, cognitive stages (LPP) than High risk women, who show such biases already at early, perceptual stages (N170). Biased and accelerated visual processing of certain kinds of bodies may thus be a hallmark of women at risk of body image disturbance (see also Groves et al., 2017, for other evidence of accelerated visual processing). Low risk women may instead exhibit gender-sensitive effects at later, cognitive stages that are indicative of motivational or aesthetic processing, since desirable female bodies elicited larger LPPs than desirable male bodies in this group (Gable & Harmon-Jones, 2013; Horndasch et al., 2012; Horndasch, et al., 2018; Jacobsen, 2013). In contrast, High risk women showed gender-sensitive LPP effects biased toward less desirable bodies, which was not seen in any other group. This is likely not indicative of motivational or aesthetic processing in the same way as it is for Low risk women but supports previous research showing heightened LPP amplifications related to preoccupation (Horndasch, Heinrich, Kratz, & Moll, 2012; Mai et al., 2015). Uusberg et al. (2018) found stronger P3 and LPP responses to self-images that were enlarged (vs. reduced in body size) in women who showed clinical symptoms of preoccupation with body size (above clinical cut-off on the Eating Disorder Assessment Scale; Akkermann, 2010) while no such differences were seen for images of others. Our high-risk women, who unlike Uusberg et al.'s sample also had a history of ED or BDDs, may be showing a similar effect for others' bodies. That is, they may process size differences in others' bodies, with a bias toward less desirable (larger) bodies, which Uusberg et al.'s women only processed for their own but not others' bodies. It is possible that the 'fear of fatness,' which is a preoccupation in women with EDs, is driven by an evaluative mechanism that is enhanced in this manner. Furthermore, Cui et al., (2019) showed that unattractive faces elicit larger LPPs than attractive faces only when aesthetic judgements where task-relevant, but not when goodness of character was judged. Therefore, the LPP differences seen in our high-risk group may further reflect the mandatory nature of aesthetic evaluations of bodies even under conditions when this is not relevant to the task. Importantly, these effects only appear to characterise at-risk female populations, but are not present in men at risk of developing MD.

In sum, these findings suggest that in addition to N170, LPP amplitudes could be a considered a potential biomarker for body desirability and heightened body image concerns, at least in women. Future studies of body image should therefore include LPP measures more routinely.

In Experiment 2, behavioural inversion effects were observed across our sample, with upright bodies being identified faster and more accurately than inverted bodies, which indicates configural processing of upright bodies. Although behavioural BIEs were statistically present for both stimulus genders, we also found that male body stimuli elicited much larger behavioural BIEs than female body stimuli. According to some accounts (e.g., Bernard et al., 2018), this pattern might suggest greater objectification of female than male bodies. However, this was not replicated in ERPs for male and female bodies (see below), which argues against objectification accounts.

Unexpectedly, we also found that risk groups were characterised by larger (rather than smaller) and gender-sensitive BIEs: behavioural BIEs were larger for male than female body stimuli in high-risk men and were statistically absent for female bodies in this group. Although BIEs appeared similar for male and female bodies in High risk women, they were statistically absent for male bodies in this group. This suggests that High risk participants only show reliable behavioural BIEs for bodies of their own gender. Low risk participants showed BIEs for all bodies. Gender-sensitive risk-related BIEs like this were replicated in ERPs only for High risk men (see below) but were less characteristic of High risk women's ERPs. Overall, the presence of BIEs and the finding that such BIEs were not clearly smaller in those at risk (although they were absent in some conditions) does not support the hypothesis that those at risk have reduced configural processing of bodies (Beilharz et al., 2016; Duncum et al., 2016; Feusner, Moller, et al., 2010; Groves et al., 2020; Mundy & Sadusky, 2014; Urgesi et al., 2012; 2014), which should have led to reduced BIEs.

We found that female bodies elicited a larger overall N170 than male bodies in all participants. This is similar to the findings of Experiment 1 and to other existing research (Alho et al., 2015; Groves et al., 2017; Hietanen & Nummenmaa, 2011). BIEs were seen at N170 in terms of larger N170 amplitudes for inverted than upright body stimuli, indicating configural processing of upright bodies. The N170 BIE was larger in women than in men. Although BIEs were also somewhat larger in response to female than male body stimuli, this difference was not significant. This was in contrast to behavioural BIEs, which were larger to male than female bodies, and also argues against objectification accounts of gendered body perception (see Bernard et al., 2018).

Like behavioural BIEs, N170 BIEs were not related to risk group in gender-sensitive terms. However, this was true for high-risk men only. Unlike any other group, high-risk men consistently showed larger inversion effects to male than female body stimuli in both behavioural and N170 data. Gender-sensitive BIEs biased toward one's own gender may thus indicate a risk marker of this group specifically.

We found that N170 BIEs also related to risk more generally in terms of hemispheric imbalances: higher risk groups showed stronger left- than right-hemispheric BIEs, while low-risk groups had more balanced BIEs across hemispheres. This was true for both male and female high-risk participants, which suggests that hemispherically imbalanced N170 BIEs may be a potential biomarker of risk for developing body image disorders such as MD, BDD or EDs.

Interestingly, and fitting with the hemispheric differences mentioned above, N170 BIEs were source-localised to left occipitotemporal cortex in High risk women. This again suggests the mandatory involvement of the FBA in this group, but this time in the left hemisphere. High risk men (and all Low risk groups) also showed some neural sources in this same region, but their BIEs were more strongly localised again to anterior prefrontal cortex. This indicates that in High risk men both passive viewing and discrimination of bodies may invoke processes related to memory, mentalising and multiple task coordination (Gilbert, Spengler et al., 2006). Source localisations in High risk women were also similar in both tasks, with the exception that the passive viewing of bodies invoked predominantly right-lateralised body-selective regions, while the more demanding visual discrimination of others' bodies (inversion task) invoked predominantly left-lateralised body-selective regions. We will return to a discussion of hemispheric differences in body perception as biomarkers later in this chapter.

**Behavioural and ERP markers of body perception systematically relate to self-reported ED, BDD and MD symptomology**

**Exploratory analysis**

Behavioural and ERP findings were correlated with scores on each of the BIC measures to assess the relationship with body image related symptoms. There were more such relationships for women than for men, with some notable exceptions for BIEs.

In Experiment 1, the overall gender-sensitive effects at N170 and LPP did not correlate with any body image measures in men and in women, except that women with larger N170 gender-sensitive effects scored higher on EDI personal alienation. While this goes some way toward supporting gender-sensitive N170 effects as a biomarker of body image disturbance in women, it is also true that Groves et al. (2017) had found stronger positive correlations with more EDI scales. The desirability differences in gender effects at N170 and LPP did not correlate with any body image measures in men. However, there were interesting correlations in women that suggest negative body image and upward social comparison may be linked with desirability- and gender-sensitive effects at N170 and LPP. Women with stronger N170 gender differences for more desirable than for less desirable bodies (i.e., differences as seen in our High risk women) had less strong beliefs that others have control over their appearance (OOBCS control). Women with stronger LPP gender differences for less desirable than for more desirable bodies (i.e., differences as seen in our High risk women) had higher drive for thinness and body dissatisfaction (EDI-3), higher body shame (OBCS shame) and viewed their own and others' bodies more from an outside observer's perspective (OBCS and OOBCS surveillance).

In Experiment 2, there were some correlations between questionnaire scores and BIEs in accuracy (but not RTs or N170) in men. We found that men with smaller BIEs in accuracy (i.e., as more characteristic of our high-risk group) had higher levels of muscularity-oriented disordered eating psychopathology (EMS total). Gender differences in BIEs showed contradictory correlations for RTs and accuracy, such that greater BIC symptomology was both associated with larger gender differences in BIEs in RTs and with smaller gender differences in BIEs in accuracy. Men with higher scores on MDDI total, greater discrepancies between actual and ideal fat-free muscle mass, greater internalisation of body ideals and greater pressures to follow those ideals (SATAQ) had larger gender effects in BIEs in RTs (i.e., stronger BIEs to male than female bodies as seen in our high-risk group). Men with more MDDI appearance intolerance and greater internalisation of muscle ideals (SATAQ) had smaller gender differences in BIEs in accuracy. Together with other findings, this suggests a number of things. One is that larger (rather than smaller) BIEs in RTs. especially for bodies of one’s own gender, may be indicative of body image disturbance in men. Another is that the accuracy of body discrimination in body inversion tasks may be the more reasonable marker of MD symptomology in men because this measure behaved in line with expectations, such that reduced BIEs, suggestive of reduced configural processing, were associated with increased BIC symptomology in men. In either case, our findings suggest that atypical configural body representation is not only present in women with anorexia (Urgesi et al., 2014), with (subclinical) dysmorphic concern (Mundy & Sadusky, 2014) or with a history of eating and body dysmorphic disorders (Groves et al., 2020), but that it might extend to men at-risk of MD.

In women, correlational findings were more straightforward, but nevertheless contradicted expectations. Greater BIC symptomology was associated with larger (not smaller)

BIEs in RTs and in accuracy, as well as with larger gender differences in BIEs, was not associated with N170 BIEs, but was associated with greater hemispheric differences in N170 BIEs. We found that women with larger BIEs in RTs had higher asceticism (EDI) and viewed their body more like an outside observer (OBCS surveillance). Women with larger BIEs in accuracy also had lower self-esteem and more interpersonal insecurities (EDI), as well as less strong beliefs that others have control over their own appearance (OOBCS control). BIC symptomology correlated with gender differences in BIEs in accuracy but not in RTs. Women with larger gender effects in BIEs in accuracy (i.e., stronger BIEs to male than female bodies; slightly more characteristic of our High risk group) also had more bulimic symptoms (EDI). Therefore, it appears that larger BIEs and larger gender differences in BIEs (larger BIEs to male than female bodies) are associated with increased risk of body image disturbance. This contradicts what was hypothesised, but is in line with risk-group-based differences seen in behavioural and ERP data in that they do not support the hypothesis that those at risk have reduced configural processing of bodies (Beilharz et al., 2016; Duncum et al., 2016; Feusner, Moller, et al., 2010; Groves et al., 2020; Mundy & Sadusky, 2014; Urgesi et al., 2012; 2014), One potentially important set of correlations emerged from the hemispheric differences in N170 BIEs: women with more hemispheric imbalances (i.e., smaller BIEs in right hemispheres and larger BIEs in left hemispheres) also report more eating disorder symptoms (several EDI measures) and a greater tendency to view their own body from an external perspective (OBCS surveillance). This is in line with risk-group-based differences in hemispheric imbalance and will be discussed later in this chapter.

These findings suggest that effects of body inversion and their relations with measures of body image disturbance may differ between men and women, which is opposite to what was originally hypothesised. It is also clear that the power of BIEs as markers of body image disturbance warrants further investigation, especially with gendered bodies and low- and high-risk populations. Here we appear to show more evidence that risk of body image disturbance is related to increased (rather than reduced) body inversion effects in brain and behaviour. A potentially important biomarker of at-risk populations also emerged: hemispheric imbalances in N170 effects of body inversion. This will be discussed next.

## Hemispheric asymmetries in N170 Body Inversion Effects as potential biomarker of at-risk populations

### Planned analysis

Hemispheric imbalances in BIEs in high-risk groups are consistent with reports of the left-lateralised structural abnormalities in body-selective cortical regions and body image distortions in women with eating disorders (Smeets & Kosslyn, 2001; Suchan et al., 2010, 2013). Our findings extend such observations of hemispheric asymmetries to women who have recovered from eating disorders as well as to an at-risk population of men. Together, this strongly suggest that, unlike other measures taken in the present study, hemispheric imbalances in N170 BIEs may be the most generalisable biomarker of body image disturbance risk.

Left-hemispheric abnormalities in eating disordered women are thought to reflect atypical local, feature-based processing in the left hemisphere (see Fink et al., 1996), or an imbalance between feature-based and configural processing due to reduced connectivity between left EBA and FBA (Suchan et al., 2013), which may relate to ED symptoms of excessive attention to body features at the expense of holistic processing (e.g., Lang et al., 2014; Lopez et al., 2008; Urgesi et al., 2012, 2014). Body inversion effects indicate a switch from global, configural encoding of upright bodies to feature-based encoding of inverted bodies, which requires the recruitment of additional neural resources that becomes reflected in N170 enhancements. It may therefore be surmised from our findings that stronger left-than-right N170 body inversion effects are a biomarker of persons at risk of body image disorders, underpinned by reduced connectivity between the left-lateralised cortical structures related to different aspects of the encoding of the human body form (configural vs. analytical).

These cortical structures may comprise a larger network including EBA, FBA and superior and inferior parietal cortex (Suchan, Vocks, & Waldorf, 2015). Although body-sensitive N170 is typically source-localised to EBA (Thierry et al., 2006; Meeren, de Gelder, Ahlfors, Hämäläinen, & Hadjikhani, 2013) and is modified by TMS to the EBA (Sadeh et al., 2011), it is likely that both EBA and FBA contribute to N170 body-sensitivity effects. This is because N170 is strongly modified by changes in body orientation (i.e., BIEs) and the structural relations between bodily features (e.g., the present study; Bauser & Suchan, 2013; Stekelenburg & de Gelder, 2004; Minnebusch, Suchan, & Daum, 2009; Minnebusch et al., 2010), which reflects the influence of the FBA - the structure purported to support configural body representation (e.g. Bauser & Suchan, 2015; Peelen & Downing, 2005; Schwarzlose, Baker, & Kanwisher, 2005; Taylor et al., 2007, 2010; Urgesi et al., 2007, 2014). In support of this, we source localised effects in the N170 time range to structures containing FBA rather than EBA in the present study, at least in women with a history of eating disorders. Superior and inferior parietal cortices likely contribute too because they are, like EBA and EBA-FBA connectivity, underactive in eating disorders (Esposito, Cieri, di Giannantonio, & Tartaro, 2018; Gaudio & Quattrocchi, 2012; Uher et al., 2005; Vocks et al., 2010; Zhu et al., 2012; but see Wagner, Ruf, Braus, & Schmidt, 2003) and are involved in (self-related) body processing (e.g., Hodzic et al., 2009; Vocks et al., 2010).

### Exploratory analysis

In further support of hemispheric asymmetries in N170 BIEs as a biomarker of ED, BDD and MD risk, we have shown that they systematically related to symptoms of eating disorder and objectified body awareness in women. They did not relate to any symptoms of MD or body image in men, however. This may suggest that although the underlying cortical machinery (interplay between configural and feature-based processing in a cortical network comprising EBA, FBA, superior and inferior parietal cortices) may be similarly imbalanced in at-risk men and women, it relates more directly to overt symptoms in women. Configural processing of faces is more right-lateralised in men and more bilateral in women (Godard, Leleu, Rebaï, & Fiori, 2013; Proverbio, Riva, Martin, & Zani, 2010; Tiedt et al. 2013). If the same is true for bodies, then left-lateralised structural anomalies in connectivity may have more severe consequences for other, more overt body-related behaviours in women than in men. Another, simpler explanation may be that effects were stronger in our at-risk women because they had received a clinical diagnosis at some point in the past, which was not the case for our at-risk men.

## Limitations

The interpretation of our findings must consider some limitations. Firstly, participants were not clinically assessed for MD, AN, bulimia, or other mental health issues. It is therefore possible that ED/BDD history participants had not experienced the illnesses they claimed to and that other mental health conditions were not disclosed during the recruitment procedure.

Secondly, we chose to median split data from male participants into two MD groups (high and low symptoms), which it could be argued, might reduce disease-specific findings. However, whilst the MDDI has a proposed cut-off score which has been increasingly adopted in empirical research studies, the proposed cut-off score is only employed to indicate heightened MD symptoms, and not used as a formal clinical cut-off score for MD diagnosis (Hildebrandt, Langenbucher, & Schlundt, 2004). Therefore, adhering to the MDDI cut-off score would not alter the applicability of these findings to individuals with a clinical diagnosis of MD. By using a median split, we were able to establish visual body perception differences between individuals at high and low risk of MD while also keeping group sizes relatively similar. It could be argued that we should have treated our female high and low risk groups the same way as the male groups (e.g., using EDI median split as a basis to divide groups). However, this may have reduced our ability to compare findings with other studies in the literature that have used presence and absence of a clinical history of ED/BDD as an indicator of high risk (e.g., Groves et al., 2017). Clinical history is likely also a more reliable indicator of risk than a median split of self-reported symptoms and should therefore be preferentially used whenever possible.

## Conclusions

This is the first study to demonstrate that the time course of visual processing in populations at risk of ED, BDD and MD differ. High risk women (but not men) showed gender-sensitivity in ERPs. High-risk women showed altered and gender-sensitive body inversion effects in ERPs and behaviour. N170 effects in high-risk women were source localised to body-selective regions in occipitotemporal cortex (FBA), suggesting mandatory body processing regardless of task requirements in this group. High risk men also showed some atypical body inversion effects. Importantly, both high risk men and women were characterised by hemispheric imbalances in N170 body inversion effects. Our findings show that stronger left-than-right N170 body inversion effects are a potential biomarker of persons at risk of body image disorders, underpinned by reduced connectivity between the cortical structures related to different aspects of the encoding of the human body form. Neuroimaging studies have already shown that the connectivity between EBA and FBA is underactive and maladapted in those with EDs (Suchan et al., 2010, 2013, 2015, Uher et al., 2005). The present results therefore add to this body of literature, providing support for the notion that visual body processing is modulated by body image in men too and may be a predisposing factor for MD. Future studies should seek to directly address the potential mechanisms underlying visual processing difference within populations with a MD clinical diagnosis, which could potentially provide further insight into body processing across MD populations.

# Chapter 3 The association between interoceptive sensibility and muscularity-oriented disordered eating in resistance training exercisers is partly explained by muscle dysmorphia symptomology and supplement usage

# Abstract

Lower interoceptive sensibility is commonly associated with less positive body image, more negative body image, and greater body image disturbances (e.g., Brown et al., 2017; Cascino et al., 2019; Daubenmier, 2005; Jenkinson et al., 2018; Myers & Crowther, 2008; Todd, Aspell, Barron, & Swami, 2019a; Todd, Aspell, Barron, & Swami, 2019b). Which is often considered to be arise as a result of excessive focus on the external, aesthetic characteristics of the body (Ainley & Tsakiris, 2013; Badoud & Tsakiris, 2017). This study aimed to examine the relationship between interoceptive sensibility and the muscularity-oriented disordered eating among resistance-training exercisers, and to explore the mediating role of muscle dysmorphia symptomology and appearance and performance enhancing supplement usage in this association. This online questionnaire-based study included a sample of 126 resistance-training exercisers between 18 and 65 years (*M* = 31.61, *SD* = 10.04; 56.3% males). Using a multi-item questionnaire, interoceptive sensibility, muscularity-oriented disordered eating, muscle dysmorphia symptomology, and appearance and performance enhancing supplement usage were assessed. To examine the mediating effects of muscularity-oriented disordered eating and appearance and performance enhancing supplement usage on the association between interoceptive sensibility and muscularity-oriented disordered eating, the bootstrapping technique was performed.

Interoceptive sensibility significantly predicted muscularity-oriented disordered eating. Muscle dysmorphia symptomology, and appearance and performance enhancing supplement usage appeared to significantly partially mediate the relationship between interoceptive

sensibility and muscularity-oriented disordered eating. These initial findings represent the first direct demonstration that increased interoceptive sensibility systematically relates to muscularity-oriented disordered eating. Unlike previous research, which has linked lower interoceptive sensibility to eating disorder symptomology and negative body image, our study shows the opposite in resistance training exercisers: heightened interoceptive sensibility can lead to greater pathological engagement towards muscle-oriented eating. These findings may contribute to muscularity-oriented disordered eating diagnostic criteria that are distinct from other eating disorders characterised by body image disturbances.

# Introduction

The term interoception refers to the processing of stimuli originating inside the body, such as feelings of hunger and heartbeats (Craig, 2003; Khalsa et al., 2018). It represents the processing of the body's physiological condition (Craig, 2002), encompassing diverse multimodal signals. The sense of the mainly visceral body is often expanded to signals detected by surface temperature receptors and nociceptors (e.g. Cameron, 2001). At the physiological level, interoception serves the critical biological function of homeostasis, ensuring the stability of the biological organism. At the psychological level, it is a key component in many theories of emotions suggesting that the extent of an individual's sensitivity to bodily signals is strongly linked to the experience and regulation of emotions (e.g., Füstös et al., 2013). In psychology, interoception is mainly studied in relation to our ability to become aware of interoceptive states. Thus, beyond the homeostatic regulation that they serve, interoceptive states. There are three differing aspects of interception: objective, subjective and metacognitive. The objective aspect refers to interoceptive accuracy which reflects the extent to which one can detect internal bodily sensations (Garfinkel et al., 2015). The subjective aspect refers to interoceptive sensibility which reflects an individual's personal account of how they experience internal sensations and the degree to which they feel engaged by interoceptive signals (Garfinkel et al., 2015). The metacognitive aspect is referred to as interoceptive awareness which reflects the correspondence between objective interoceptive accuracy and subjective report (Garfinkel et al., 2015).

Body image refers to external appearance-related perceptions, affects, and cognitions (Cash, 2004; Cash & Smolak, 2011). Body image is the conscious mental representation of our own body (Berlucchi & Aglioti, 2010), consisting of multiple facets: cognitive (thoughts about our body), affective (feelings about our body), perceptual (perceptions of our body), and behavioural (behaviours we engage in if we are dissatisfied with our body) (e.g., de Vignemont, 2010; Grogan, 2021). All of these facets are thought to be affected in body image disturbances, such as those contributing to the symptomology of ED, BDD, and MD (see Cafri, Olivardia, & Thompson, 2008; Castellini et al., 2013; Hildebrandt et al., 2006; Mohr et al., 2010; Pope Jr et al., 1997; Thomas, Tod, & Lavallee, 2011; Vocks, Busch, Schulte, Grönermeyer, Herpertz and Suchan, 2010). MD’s defining feature is the belief that one's body is small, insufficiently muscular and or lean, despite one’s body being objectively muscular in size (Grieve, 2007). An excessive drive for muscularity is a core component of MD (Pope, et al., 1997), alongside appearance intolerance, obsessive exercise (Murray et al., 2012), and perfectionism (Davis & Scott-Robertson, 2000), resulting in significant distress and functional impairment (such as diet and/or exercise regimes interfering with work/studies) (Hildebrandt et al., 2006).

Both Interoception and body image are essential components of personal identity and contribute to the regulation of human behaviour (Cash, 2004; Craig, 2009; Damasio, 2012). However, interactions between the two constructs are complex because they are both multidimensional (Berntson & Khalsa, 2021; Khalsa et al., 2018), and because variables such as age, gender, and national and cultural context are known to interact with each construct (e.g., interoception: Chentsova-Dutton & Dzokoto, 2014; Freedman et al., 2021; Ma-Kellams, 2014; body image: Swami, 2015, 2018; Swami et al., 2010). To that end, the aim of the present study was to examine whether associations between interoception (specifically interceptive sensibility) and body image that have been previously identified in eating disorder samples can be replicated in muscle-oriented disordered eating in resistance training exercisers. In recent years, interoceptive processing has been parcellated into numerous components that span both conscious and unconscious levels of processing (Garfinkel et al., 2015; Khalsa et al., 2018, 2021; Suksasilp & Garfinkel, 2022). Of these components, the present work focuses on interoceptive sensibility, which primarily refers to the self-reported salience of interoceptive stimuli (e.g., how fast one's breathing) (for discussions of interoceptive terminology, see Khalsa et al., 2018, 2021; Mehling, 2016). Interception itself may be considered a broader construct: Mehling (2016) has proposed that it also encompasses cognitive and behavioural aspects, such as appraisals and beliefs surrounding interoceptive stimuli. The components of interoceptive sensibility as outlined by Mehling can be measured using the Body Perception Questionnaire-Short Form (BPQ: Cabrera et al., 2018) which comprises 3 subscales (i.e., body awareness; supradiaphragmatic reactivity; and subdiaphragmatic reactivity).

Like interoception, body image can be considered a multifaceted construct comprising body-related perceptions, affects, and cognitions (Cash, 2004; Cash & Smolak, 2011). Research indicates that negative and positive body image are independent and distinct constructs, rather than opposite ends of the same spectrum (Tylka, 2018; Piran, 2019; Tylka & Wood-Barcalow, 2015). Negative body image refers to the negative thoughts, perceptions, and feelings a person has about their body (Cash & Pruzinsky, 2002). It comprises many facets, including appearance dissatisfaction, body surveillance, body shame, and weight preoccupation (Cash, 2004; Cash & Pruzinsky, 2002). Positive body image refers to “an overarching love and respect for the body that allows individuals to (a) appreciate the unique beauty of their body and the functions that it performs for them; (b) accept and even admire their body, including those aspects that are inconsistent with idealized images; (c) feel beautiful, comfortable, confident, and happy with their body, which is often reflected as an outer radiance, or a “glow;” (d) emphasize their body's assets rather than dwell on their imperfections; and (f) interpret incoming information in a body-protective manner whereby most positive information is internalized and most negative information is rejected or reframed.” (Wood-Barcalow et al., 2010, p. 112).

**Body Image and Interoception**

Recent theorising suggests that less accurate interoception could result in exteroceptive (e.g., visual, tactile and proprioceptive) cues contributing relatively more strongly to bodily awareness (Tajadura-Jiménez & Tsakiris, 2014; Tsakiris, Jiménez, & Costantini, 2011), which could, in turn, result in an excessive focus on the outward, aesthetic characteristics of the body (Ainley & Tsakiris, 2013; Badoud & Tsakiris, 2017) and foster negative body image in those at risk of a body image related disorder (Fredrickson & Roberts, 1997). Indeed, participants with body image disturbances and eating disorder symptomology have been found to prioritise exteroceptive cues over interoceptive cues in manipulations of body ownership, such as the rubber hand illusion (Eshkevari, Rieger, Longo, Haggard, & Treasure, 2014; see also, 2012; Mussap & Salton, 2006), size weight illusion (Case, Wilson, & Ramachandran, 2012) and body swapping (Petkova & Ehrsson, 2008), where feeling detached from one's own body appears to be a key experience that distinguishes clinical participants from non-clinical participants

(Stanghellini, Castellini, Brogna, Faravelli, & Ricca, 2012; Stanghellini et al., 2015). A growing number of studies support the theory that lower levels of interoceptive accuracy and interoceptive awareness contribute to body-image concerns (for a review, see Badoud & Tsakiris, 2017). The majority of this research has reported that self-reported lower interoceptive sensibility is associated with less positive body image, more negative body image, and greater body image disturbances (e.g., Brown et al., 2017; Cascino et al., 2019; Daubenmier, 2005; Jenkinson et al., 2018; Myers & Crowther, 2008; Todd, Aspell, Barron, & Swami, 2019a; Todd, Aspell, Barron, & Swami, 2019b). For instance, Todd et al., (2019a; 2019b) found that greater interoceptive sensibility (measured via the Multidimensional Assessment of Interoceptive Awareness questionnaire (Mehling et al., 2012)) was significantly associated with more positive body image in both adolescent boys and girls (Todd et al., 2019a), and female adults (Todd et al., 2019b).

Associations between body image and interoceptive accuracy have also been identified. Specifically, research has indicated that lower cardiac interoceptive accuracy (assessed using the heartbeat tracking task; e.g., Schandry, 1981) is significantly associated with indices of negative body image, including higher body dissatisfaction (e.g., Emanuelsen & Köteles, 2015; Drew, Ferentzi, Tihanyi, & Köteles, 2020), self-objectification (Ainley & Tsakiris, 2013), and body image disturbances (e.g., Klabunde et al., 2013; Pollatos et al., 2008). Conversely, higher cardiac interoceptive accuracy has been associated with greater body satisfaction (Duschek, Werner, del Paso, & Schandry, 2015). The same trends have also been identified using assessments of gastric sensitivity (i.e., a two-stage water load task; van Dyck et al., 2016), where a lower sensitivity to satiation signals has been associated with more negative body image and symptoms of body image disturbances (van Dyck et al., 2016) and a greater sensitivity to satiation signals has been associated with more positive body image (Todd et al., 2020; Todd, Cardellicchio, Swami, Cardini, & Aspell,), and has been regarded as an essential perquisite for emotion regulation (Füstös, Gramann, Herbert, & Pollatos, 2013). Furthermore, across ED populations, higher self-objectification has been found to result in less attentional capacity to direct towards internal bodily signals (Ainley & Tsakiris, 2013), and consequently such persons receive less feedback and signals to process from the internal body (Pollatos et al., 2008).

From this brief summary of the extant literature, associations between body image and explicit facets of interoception are well-documented (for a further review, see Badoud & Tsakiris, 2017). However, to our knowledge, no previous study has examined direct associations amongst regular resistance training exercisers at risk of MD and muscle oriented disordered eating. Previous research has suggested that bodybuilders have a heightened interoceptive sensibility compared to individuals of other sports (Blouin, & Goldfield, 1995) and to non-bodybuilders (Babusa & Túry, 2012), where increased interoceptive sensibility was associated with increased MD symptoms (Babusa & Túry, 2012). However, other research has demonstrated that interceptive awareness does not relate to muscle belittlement (feeling that one is less muscular than h is) in male college students (Olivardia, Pope, Borowiecki III, & Cohane, 2004). Both studies used the Interoceptive Awareness subscale of the Eating Disorder Inventory (Garner, Olmstead, & Polivy, 1983), therefore more research is needed using scales that are more specific to MD populations.

**Appearance and Performance-Enhancing Drugs and Interoception**

Prevalence of legal APED use has been estimated to be as high as 90% among elite athletes and approximately 40% of the amateur athlete and gym-using population (Barkoukis, Lazarus, Lucidi, & Tsorbatzoudis, 2015; Burns, Schiller, Fada, Merrick & Wolf, 2004). Legal

APED's are commonly marketed as increasing the user's speed, endurance, performance, and strength, as well as reducing recovery time and modifying body shape/size (Muller, Gorrow, & Schneider, 2009). Research suggests that regular supplement use may be a crucial factor in the development and risk for illegal APED use independent of sports participation, body image disturbance, or other illegal drug use. Both drive for muscularity and supplement use have been positively associated with muscle-oriented ED pathology in men (Chittester & Hausenblas, 2009; Tod, & Edwards, 2015; Hildebrandt, Harty, & Langenbucher, 2012). Common muscle-oriented ED pathology in men includes increased caloric intake, bingeing, overconsumption of protein-based foods, and restriction of fats and carbohydrate-based foods (Griffiths et al., 2013; McCreary & Sasse, 2002; Murray, Griffiths, & Mond, 2016; Petrocelli et al., 2008).

Bodybuilders using anabolic steroids have previously reported increased intercoeptive sensibility compared to non-using bodybuilders (Blouin & Goldfield, 1995; Kanayama, Barry, Hudson, & Pope Jr, Harrison, 2006). Furthermore, interoceptive sensibility increases with steroid usage, where heavy users self-reported greater interoceptive sensibility than experimental and non-users on modified version of the EDI (Garner et al., 1983) interoceptive awareness subscale (Kanayama, et al., 2006). This suggests that, unlike female populations with EDs, bodybuilding populations with ED pathologies may have increased interoception, perhaps as a result of, or otherwise linked with, APED use.

**Disordered Eating Behaviour and Interoception**

Extensive research has demonstrated deficits in interoception across disordered eating types and interoceptive modalities, suggesting that interoception may constitute a transdiagnostic feature of disordered eating (Dourish, Rotshtein, Spetter, & Higgs, 2019; Jenkinson, Taylor, &

Laws, 2018; Vervaet, Puttevils, Hoekstra, Fried, & Vanderhasselt, 2021; for a review, see Martin et al., 2019). Deficits in interoception, observed as alterations of inner body perception, may be considered a crucial feature of eating disorders. The widely used EDI is a questionnaire designed to assess common traits of anorexia nervosa and bulimia nervosa (Garner et al., 1983) and it includes ‘interoceptive awareness’ as a factor. Using this questionnaire, interoceptive impairments have been noted in patients with of anorexia nervosa and bulimia nervosa (Klabunde et al., 2013; Pollatos et al., 2008) and in subclinical populations with disordered eating behaviour (Brown, Smith, & Craighead, 2010; Koch and Pollatos, 2014; Young et al., 2017). Despite extant literature evidencing the relationship between interoception and eating pathology (Martin et al., 2019), such research has been limited common measures of disordered eating without consideration of less established ED pathologies. One of these is Muscularity-oriented disordered eating, which is defined as a cluster of pathological eating attitudes and behaviours that are motivated by the pursuit of muscularity, and which may include both eating to increase leanness in addition to muscularity (Griffiths, Murray, & Touyz, 2013). Typically, this includes increased caloric intake, bingeing, overconsumption of protein-based foods, and restriction of fats and carbohydrate-based foods (Griffiths, Murray, & Touyz, 2013; McCreary & Sasse, 2002; Murray, Griffiths, & Mond, 2016; Petrocelli, Oberweis, & Petrocelli 2008). As muscle dysmorphic behaviours are triggered by the desire to increase muscularity, most thinness-oriented disordered eating measures are inconsistent with this muscularity pursuit and do not assess muscle-oriented disordered eating behaviours (Griffiths, Murray, & Touyz, 2013). This suggests that the relationship between interoception and eating pathology may differ in individuals with muscle-oriented disordered eating, as behaviours are triggered by the desire to increase muscularity and not exclusively thinness-oriented (Murray, Griffiths, & Mond, 2016).

Therefore, it is important to establish whether the known negative relationship between interoception and eating pathology extends to male and female populations categorised by muscle-oriented disordered eating.

Should the known negative relationship between interoceptive sensibility and ED pathology apply to our MD sample, then we would expect reduced interoceptive awareness to promote MD symptomology, appearance and performance enhancing supplement usage, and that increased muscularity-oriented disordered eating behaviours. As several studies suggest that interoceptive sensibility may differ in men with MD symptoms (Blouin & Goldfield, 1995; Kanayama, Barry, Hudson, & Pope Jr, Harrison, 2006), then the reverse relationship, or a lack of a relationship may be expected.

The current study put forward two mediations, MD symptomology, and appearance and performance enhancing supplement usage to develop a theoretical and empirical linkage between interoceptive sensibility and muscularity-oriented disordered eating. Figure 26 visualises a parallel mediation. It included a path between interoceptive sensibility and muscularity-oriented disordered eating and further indicated that this relationship was due to the indirect path involving MD symptomology and appearance and performance enhancing supplement usage. We also included ideal-body discrepancy measures to determine body dissatisfaction. The findings will contribute to the knowledge of behavioural and psychological mechanisms implicated by interoceptive sensibility in resistance training exercisers.

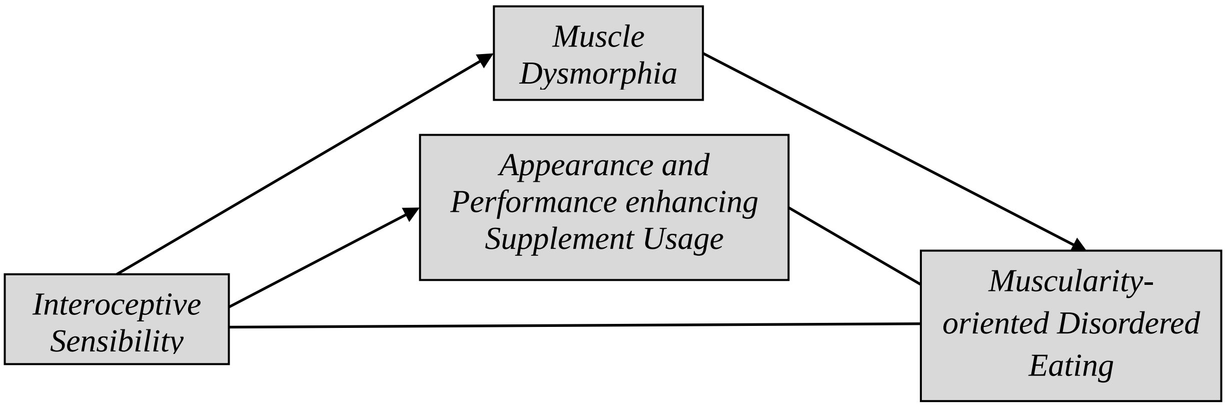



Figure 26. Parallel mediation model including interoceptive sensibility, muscularity-oriented disordered eating, muscle dysmorphia symptomology, and appearance and performance enhancing supplement usage.

## Study hypotheses

The current study examined three distinct but related symptoms associated with MD (i.e. drive for size, appearance intolerance, and functional impairment). Considering that each of the three behaviours associated with MD may have different value and implications, we additionally examined their pathways to muscle-oriented disordered eating independently. Accordingly, five working hypotheses were developed:

H1: Lower levels of subjective interoceptive sensibility would predict heightened muscularity-oriented disordered eating.

H2: Muscle dysmorphia symptomology and APES usage would mediate the relationship between interoceptive sensibility and muscularity-oriented disordered eating.

H3: Drive for size and APES usage would mediate the relationship between interoceptive sensibility and muscularity-oriented disordered eating.

H4: Appearance intolerance and APES usage would mediate the relationship between interoceptive sensibility and muscularity-oriented disordered eating.

H5: Functional impairment and APES usage would mediate the relationship between interoceptive sensibility and muscularity-oriented disordered eating.

# Method

## Participants

A priori power analyses with the Monte Carlo Power Analysis for Indirect Effects (Schoemann, Boulton, & Short, 2020) were calculated. with 1000 replications, 20,000 Monte Carlo draws per replication and a confidence level of 95%. The analyses revealed that in order to test all our hypotheses with a power of at least 0.8 and medium effect sizes, the study needed to include at least 105 participants. Thus, a total of N = 147 resistance training exercisers were initially recruited. Participants were recruited via pre-existing databases, social media platforms, and University of Essex mailing lists. A prize draw (consisting of small denominations of a total £300 Amazon e-gift cards) was offered as an incentive. Participants had to be aged 18-65 years, and been exercising regularly using resistance (e.g., weights, bodyweight, resistance bands) as part of their exercise regime for at least the last six months prior to their participation. This was to ensure that resistance training was an established aspect of their regular gym routine. To ensure participants met these criteria, age and exercise regime related questions were incorporated in the experiment.

To screen for multivariate outliers among predictor variables, we used Mahalanobis distances, Cook’s distances, and Leverage. Participants who scored above threshold values on at least two of the tests, were considered outliers and removed from analysis. In this instance, there were 3 outliers. Subsequent examination of the cases revealed that the individual response pattern across the variables were sufficiently abnormal to be deemed illegitimate respondents. Also, participants with incomplete data were removed (n=21). This left a total of 126 respondents (71 men, 55 women, age: *M* = 31.61, *SD* = 10.04). On average, participants exercised using resistance 5hrs 57mins per week (*M* = 5.96, *SD* = 4.73).

## Exclusion Criteria

Individuals who had been diagnosed with body dysmorphic disorder and/or eating disorder were not recruited. Those who had experienced a major psychiatric disorder, such as schizophrenia or bipolar disorder, were also not permitted to participate. We chose not to recruit men who had a medical diagnosis or a history of mental illness, to ensure the two groups differed as little as possible in terms of mental health. These exclusion criteria were outlined in the participant recruitment communications, as well as incorporated as questions in the online survey part of the experiment, e.g., “Have you ever experienced a physical and/or mental condition that affects the way you feel about your own body?”; “Have you been diagnosed with this/these conditions by a medical professional, and received treatment (e.g., medication, counselling)?”.

## Ethical Declaration

The study was approved by the local Ethics Committee for the Psychology Department at the University of Essex (Ethics ID: ETH1920-1045).

## Apparatus and Stimuli

## Questionnaire Measures

### Muscle Dysmorphia Disorder Inventory (MDDI)

The MDDI (Hildebrandt, Langenbucher, & Schlundt, 2004) was used to identify individuals exhibiting symptoms associated with MD (see Chapter 2 of this thesis for full details). A threshold value of > 39 points was proposed (Varangis, Folberth, Hildebrandt, & Langenbucher, 2012) and has been used in a previous studies (Lechner, Gill, Drees, Hamady, & Ludy, 2019; Longobardi, Prino, Fabris, & Settanni, 2017; Zeeck et al., 2018). In the present study, the Cronbach's α was .82 for the total MDDI, and ranged from 0.82 to 0.83 for the subscales, demonstrating good internal consistency.

### New Somatomorphic Matrix - Male (NSM-M) and New Somatomorphic Matrix - Female (NSM-F)

The New Somatomorphic Matrix–Male (NSM-M) (Talbot, Smith, Cass, & Griffiths, 2018) (Figure 27) is a perceptually equivalent and modified version of Somatomorphic Matrix Modification scale (Cafri, Roehrig, & Thompson, 2004). The NSM-F is a female equivalent of the NSM-M. The NSM-F was created for this study using figures of female bodies and rendered through Daz Studio 4.1 (www.Daz3d.com) via the same procedure as with the NSM-M (Talbot, Smith, Cass, & Griffiths, 2018).

Once presented with the NSM-M or NSM-F, participants were asked the following: (a) "Please click the location on the grid that best corresponds to your actual body", and (b) "Please click the location on the grid that best corresponds to your ideal body (i.e., the body you would most like to have as your own)". According to criterion for adequate test–retest reliability (coefficient ≥ 0.70) (Terwee et al., 2007), the NSM-M has good test-retest reliability. From the intraclass correlations coefficients (ICC) a good agreement was indicated perceived, desired, and discrepancy across both body fat and muscularity measures (ICC = 0.78-0.95, $p < .001$).

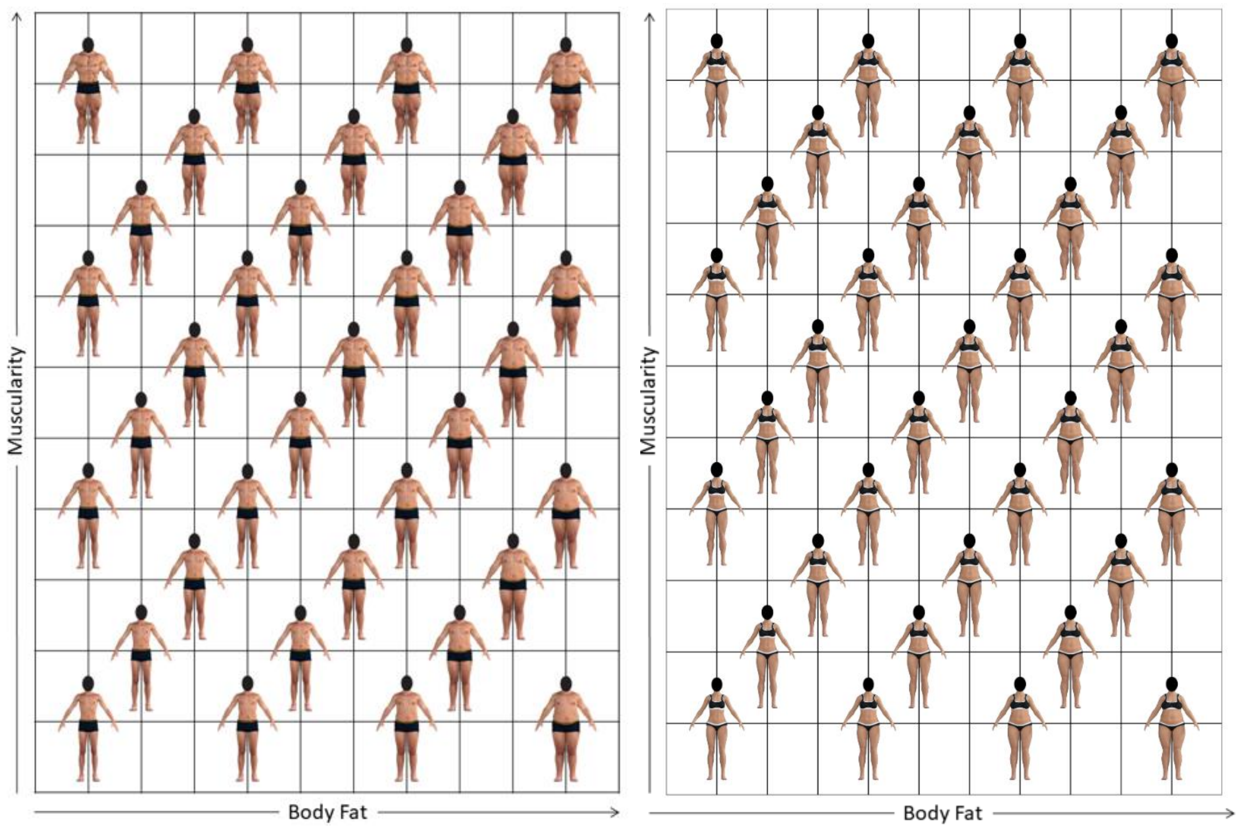



Figure 27. Left: New Somatomorphic Matrix - Male (Talbot, et al., 2018). Right: New Somatomorphic Matrix - Female (adapted from the male version). For both matrices, the x-axis displays body fat percentage ranging from 4 to 40%, increasing in increments of 4%, and the y-axis presents fat-free mass index ranging from 16.5 to 30 kg/m$^2$ (36.4–66.1 lbs/m$^2$), increasing in increments of 1.5 kg/m$^2$.

**Muscularity-Oriented Disordered Eating Test (MOET)**

The Muscularity-Oriented Disordered Eating Test (MOET) (Murray et al., 2019), is a 15-item measure of eating-related behavioural (e.g., “I have used meal replacement supplements when I felt full”), and attitudinal (e.g., “I have felt anxious when I run out of protein-based supplements”), components of muscularity-oriented disordered eating, in which items are rated on a 5-point Likert scale, ranging from “never true” to “always true”. The MOET measures eating behaviour based on the preceding 4 weeks. Higher mean scores indicate higher levels of disordered eating behaviour. The MOET has demonstrated good reliability (test-retest reliability $r$ =.75), and strong internal consistency (Ω = 0.92-0.93, 95% CI [0.90, 0.94]) (Murray et al., 2019). In the present study, the Cronbach’s α was .78 for the MOET.

**Appearance and Performance Enhancing Supplement/Substance Scale (APES)**

The Appearance and Performance Enhancing Supplement/Substance Scale (APES) (Cooper, Hicks, & Griffiths, 2019) (see Chapter 2 of this thesis for full details). For the purpose of this research only the supplement subscales were employed. In the present study, the Cronbach’s α was .78 for the supplement subscale.

**Body Perception Questionnaire Short Form (BPQ-SF)**

The Body Perception Questionnaire (BPQ-SF) (Cabrera et al., 2018) is a subjective self-report measure of interoceptive sensibility. This questionnaire consists of three different subscales with a total of 46 items. High scores on the BPQ-SF reflect high awareness of internal bodily signals (i.e., high interoceptive sensibility) and high perceived reactivity of the visceral nervous system. The BPQ-SF can be analysed regarding three subscales, namely Body awareness (26 items, example question: ‘In most situations I am aware of the following process: An urge to cough to clear my throat.'), Supradiaphragmatic reactivity (15 items, example questions: 'I have chest pains.', 'My nose is runny, even when I am not sick.', 'My heart often beats irregularly.'), and Subdiaphragmatic reactivity (6 items, example question: 'After eating I have digestion problems.'), where the latter two refer to questions about the reactivity of organs above and below the diaphragm, respectively (Cabrera et al., 2018). On all subscales, responses are given on a five-point scale, ranging from "never" to "always". In this paper, we focused on the body awareness subscale, which has been widely used in previous research (for a review, see Cabrera et al., 2018). The Body awareness subscale has demonstrated good reliability (test-retest reliability $r$ =.99), internal consistency (Ω = 0.92-0.96) (Cabrera et al., 2018), and has also been corroborated by neuroimaging studies, demonstrating its association with the insulae grey matter density and neural activity in healthy participants (Adolfi et al., 2017; Wiebking et al., 2010). In the present study, the Cronbach's α was .93 for the Body awareness subscale, .94 for the Supradiaphragmatic reactivity subscale, and .82 for the Subdiaphragmatic reactivity

## Procedure

We designed the experiment online Qualtrics (https://www.qualtrics.com). First, participants were asked to respond to a series of scales to measure interoceptive sensibility (BPQ-SF (Cabrera et al., 2017)), MD symptomology (MDDI (Hildebrandt et al., 2004)), disordered eating behaviour (MOET (Murray et al., 2019)), Body dissatisfaction (NSM-M (Talbot et al., 2018), NSM-F), and supplement use (APES (Cooper, Hicks, & Griffiths, 2019)). All participants then completed questions on socio-demographic information, self-reported age, sex, weight, height, exercise including cardio (e.g., "Over the past 6 months, which of the following aerobic (cardio) exercises have you performed?"; "What is the average time (hrs) spent for each exercise session?”), resistance training practices (e.g., “What is the average time (hrs) spent for each resistance training session?”; “What age did you start lifting weights?”), sport participation (e.g., “Which Sports do you participate in?”; “Each time you participate in a sport, what is your average participation time (hrs)?”), and dietary behaviours (e.g., “Do you follow any specific diets?”; “Do you avoid/limit quantity of any of the following food groups?”). All individuals provided their informed consent clicking agreement before starting to complete the survey, and participants were also informed about the possibility to withdraw from the survey at any stage without explanation. Participants took approximately 20 minutes to complete the survey.

## Data analysis

Descriptive statistics and correlation tests were performed to understand the sample structure and study variables. To examine mediating effects, we used a bootstrapping technique employing PROCESS macro (Hayes, 2018; Preacher & Hayes, 2004). Four parallel models were assessed. We implemented 5,000 bootstrap samples for the percentile bootstrap confidence interval, and a 95% confidence level was employed. The BCa confidence intervals are considered by Preacher & Hayes (2008) superior to the normal theory Sobel tests as they require no distributional assumptions and are less likely to lead to a Type I error. If the BCa 95% confidence interval does not include zero, we can conclude there was a significant indirect effect (at alpha = .05). Statistical assumption tests were performed before the mediation analysis. Collinearity was tested, resulting in variance inflation factors (1.08 – 1.24) and tolerances (.80 – .93) within the limits accepted for regression analysis (Cohen et al., 1983). Homoscedasticity and linearity were observed through the analysis of residual scatterplots, revealing no problems

(Tabachnick, Fidell, & Ullman, 2007). Data preparation and analyses were conducted using the IBM SPSS Statistics version 25 and the PROCESS macro version 3.5.3 for SPSS.

# Results

## Descriptive statistics

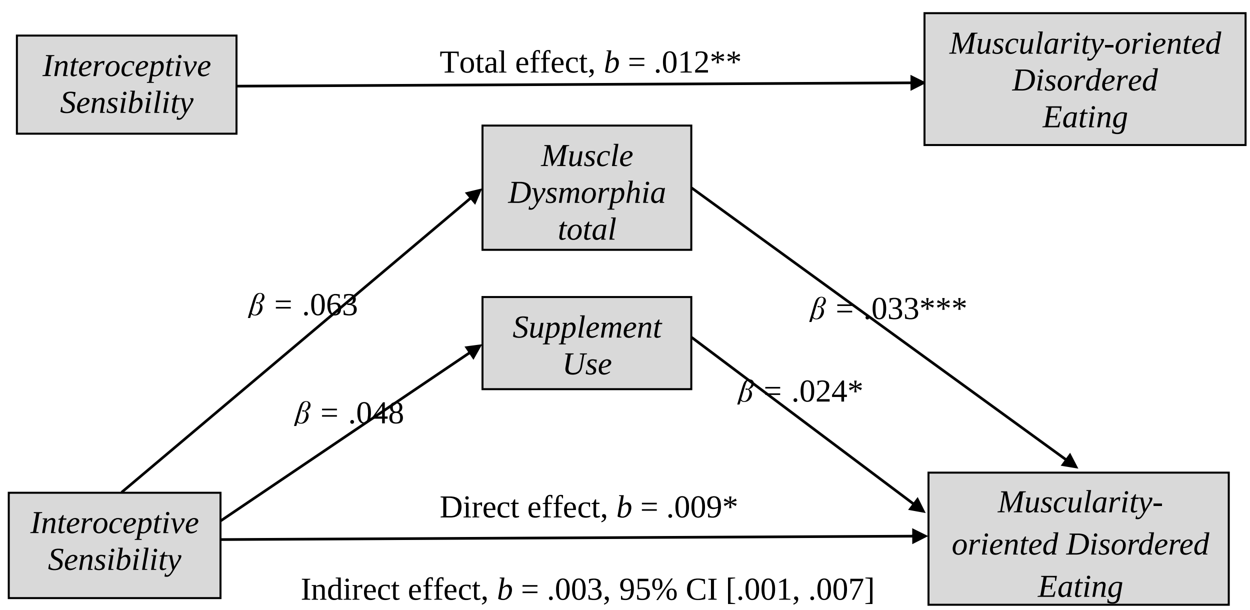
Table 7 provides information about the measured variables, including means, standard deviations, and reliabilities.

Table 7 Descriptive statistics of the measured variables.

| | *n* | *M* | *SD* |
|---|---|---|---|
| BPQ Body Awareness | 126 | 58.35 | 18.33 |
| BPQ Supradiaphragmatic Reactivity | 126 | 21.34 | 7.52 |
| BPQ Subdiaphragmatic Reactivity | 126 | 9.44 | 3.47 |
| MDDI Total | 126 | 33.71 | 8.53 |
| Drive for Size | 126 | 12.37 | 4.92 |
| Appearance Intolerance | 126 | 10.43 | 3.82 |
| Functional Impairment | 126 | 9.91 | 3.68 |
| APES Total | 126 | 9.89 | 6.11 |
| MOET Total | 126 | 1.37 | 0.79 |
| Body Fat Percentage Discrepancy | 126 | -6.77 | 8.30 |
| Fat Free Mass Index Discrepancy | 126 | 4.70 | 7.50 |

## Regression analysis

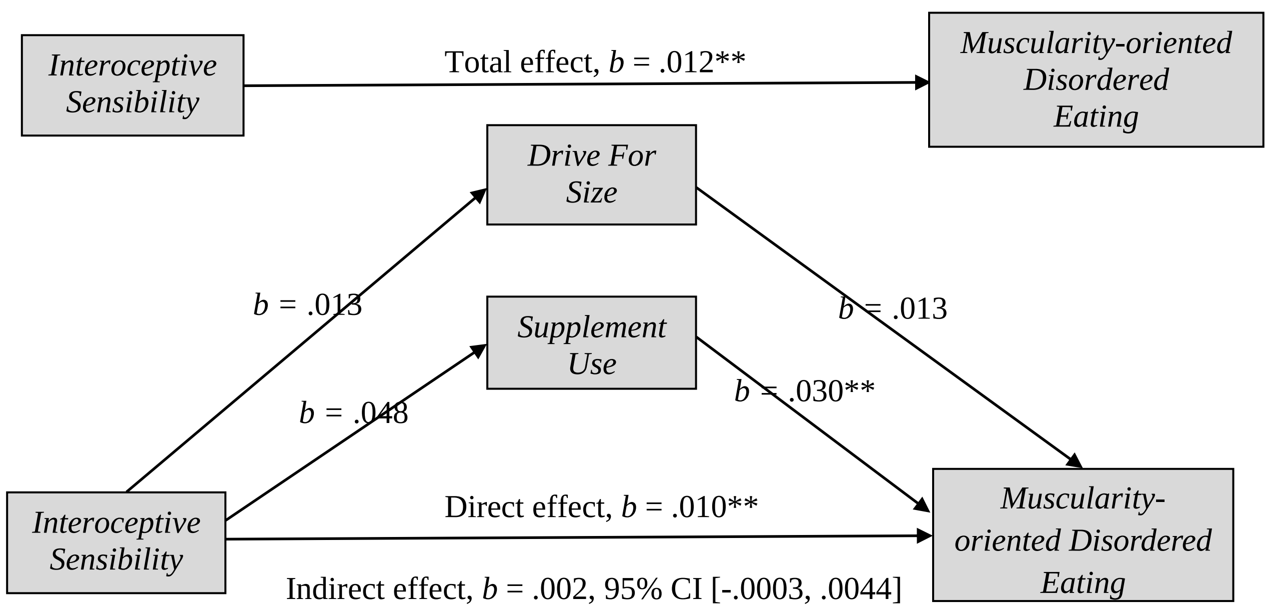
Figure 28 parallel mediation model explained 25.0% of the muscularity-oriented disordered eating variance ($F$ (3,122) = 13.52, $p < .001$). Total ($p < .01$), direct ($p < .05$), and indirect (95% BCa CI of 0.001 to 0.007) effects of increased interoceptive sensibility on increased muscularity-oriented disordered eating were significant. The model suggests the presence of partial mediation, since the direct effect, although reduced as evidenced by the significant indirect effects, remained significant when controlling for the two mediators. The indirect effects of interoceptive sensibility on muscularity-oriented disordered eating via MD ($\beta$ =.002; 95% CI [-.0047, .0054]) and supplement use ($\beta$ =.001; 95% CI [-.0003, .0033]) were both non-significant (Figure 28). There was a significant indirect effect of interoceptive sensibility on muscularity-oriented disordered eating through MD and supplement use ($\beta$ = .003, 95% CI [.0017, .0070]). Therefore, this model demonstrated that both MD and supplement use played a role in partially mediating the relationship between interoceptive sensibility on muscularity-oriented disordered eating.




*Note:* N = 126; *** $p < .001$, ** $p < .01$, *$p < .05$.

Figure 28. Structural model results. MD total.

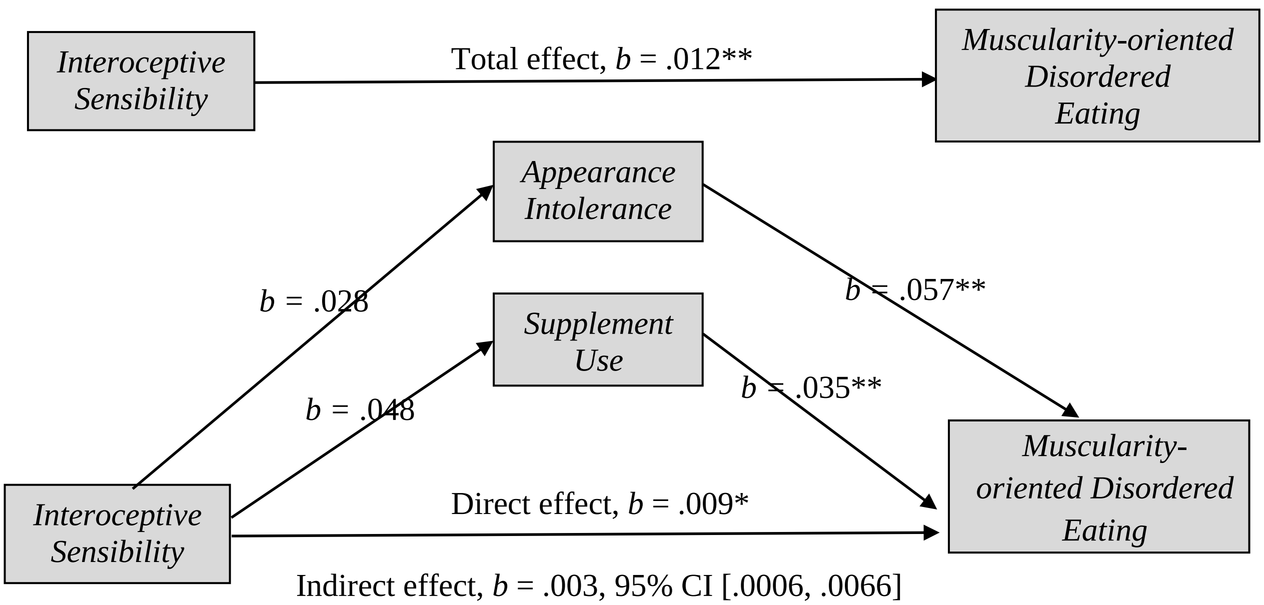
Figure 29. parallel mediation model explained 13.8% of the muscularity-oriented disordered eating variance (*F* (3,122) = 6.51, *p* < .001). Total (*p* < .01) and direct (*p* < .05) effects of interoceptive sensibility on muscularity-oriented disordered eating were significant (Figure 29). The indirect effects of interoceptive sensibility on muscularity-oriented disordered eating via drive for size (*β* =.0002; 95% CI [-.0061, .0012]) and supplement use (*β* =.001; 95% CI [-.0002, .0039]) were both non-significant. There was no significant indirect effect of interoceptive sensibility on muscularity-oriented disordered eating through drive for size and supplement use (*β* = .002, 95% CI [-.0003, .0044]). Therefore, this model suggested no mediation was present as evidenced by the non-significant indirect effects.




*Note:* N = 126; *** *p* < .001, ** *p* < .01, **p* < .05.

Figure 29. Structural model results. MD – Drive for size

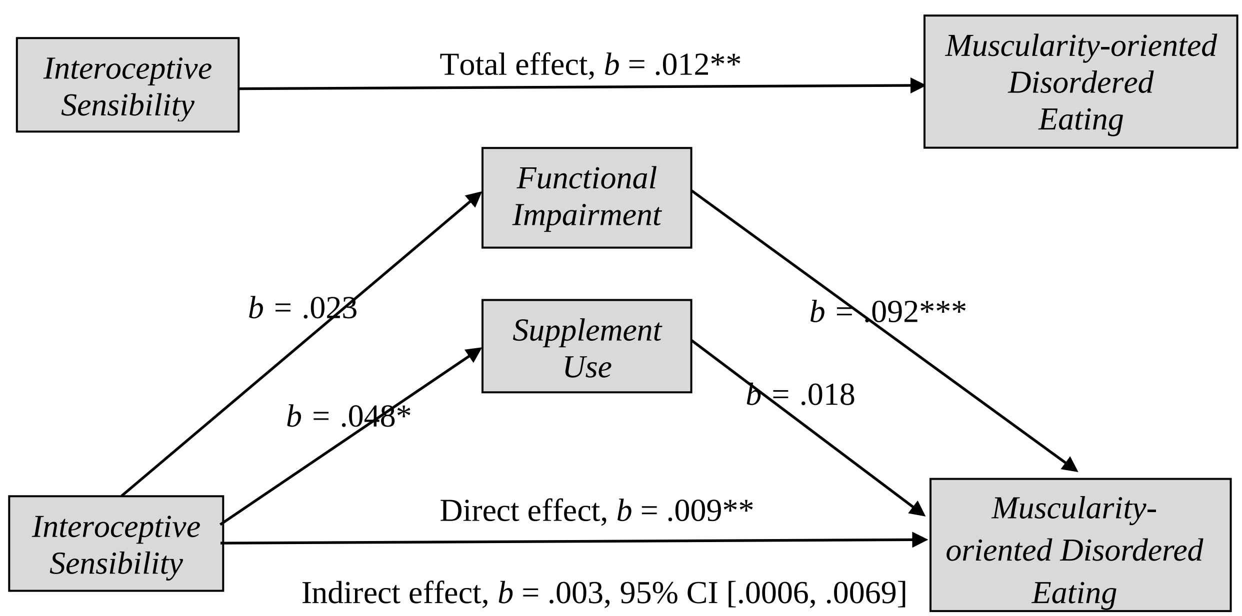
Figure 30 parallel mediation model explained 20.5% of the muscularity-oriented disordered eating variance (*F* (3,122) = 10.50, *p* < .001). Total (*p* < .01) and direct (*p* < .05) effects of interoceptive sensibility on muscularity-oriented disordered eating were significant (Figure 30). The indirect effects of interoceptive sensibility on muscularity-oriented disordered eating via appearance intolerance ($\beta$ =.002; 95% CI [-.0002, .0045]) and supplement use ($\beta$ =.0012; 95% CI [-.0002, .0044]) were both non-significant. There was a significant indirect effect of interoceptive sensibility on muscularity-oriented disordered eating through appearance intolerance and supplement use ($\beta$ = .003, 95% CI [.0006, .0066]). Therefore, this model demonstrated that both appearance intolerance and supplement use played a role in partially mediating the relationship between interoceptive sensibility on muscularity-oriented disordered eating.




*Note:* N = 126; *** $p < .001$, ** $p < .01$, *$p < .05$.

Figure 30. Structural model results. MD – appearance intolerance

Figure 31 parallel mediation model explained 30.0% of the muscularity-oriented disordered eating variance (*F* (3,122) = 17.49, *p* < .001). In this model, total (*p* < .01) and direct (*p* < .05) effects of interoceptive sensibility on muscularity-oriented disordered eating were significant (Figure 31). The indirect effects of interoceptive sensibility on muscularity-oriented disordered eating via functional impairment (*β* =.002; 95% CI [-.0013, .0061]) and supplement use (*β* =.0008; 95% CI [-.0002, .0027]) were both non-significant. There was a significant indirect effect of interoceptive sensibility on muscularity-oriented disordered eating through functional impairment and supplement use (*β* = .003, 95% CI [.0006, .0069]). Therefore, this model demonstrated that both functional impairment and supplement use played a role in partially mediating the relationship between interoceptive sensibility on muscularity-oriented disordered eating.




*Note:* N = 126; *** *p* < .001, ** *p* < .01, **p* < .05.

Figure 31 Structural model results. MD – functional impairment

# Discussion

The findings from this study represent the first demonstration that increased interoceptive sensibility (specifically, body awareness) systematically relates to increased muscle-oriented disordered eating behaviour. Unlike previous research, which has associated lower interoceptive sensibility with increased eating disorder symptomology and greater body dissatisfaction (Ainley & Tsakiris, 2013; Brown et al., 2017; Cascino et al., 2019), our study shows the opposite in resistance training gym goers of both sexes. This suggests that in resistance training gym goers, heightened interoceptive sensibility predicts muscle oriented disordered eating, and that this is partially mediated by supplement use and by overall MD symptoms, and specifically by the MD symptoms related to appearance intolerance.

Previous research has indicated that lower interoceptive sensibility is significantly associated with indices of negative body image (e.g., Ainley & Tsakiris, 2013; Drew, Ferentzi, Tihanyi, & Köteles, 2020; Emanuelsen & Köteles, 2015; Klabunde et al., 2013; Pollatos et al., 2008). However, other studies have suggested that interoceptive sensibilitymay differ in men with MD symptoms (Blouin & Goldfield, 1995; Kanayama, Barry, Hudson, & Pope Jr, Harrison, 2006), and may not apply when considering muscle-oriented disordered eating. Our findings indeed suggest that things differ contradicting our hypothesis (H1), as we found higher levels of subjective interoceptive sensibility directly predicted heightened muscularity-oriented disordered eating in resistance training gym-goers. These findings differ from previous research in ED populations, which found lower interoceptive sensibility predicts increased eating disorder symptomology (Ainley & Tsakiris, 2013; Pollatos et al., 2008). However, our findings are in line with previous research demonstrating that bodybuilders with greater MD symptoms have a heightened interoceptive awareness compared to individuals of other sports (Blouin, & Goldfield, 1995) and compared to non-bodybuilders (Babusa & Túry, 2012). Our findings add to the literature and suggest that increased interoceptive awareness may be a risk factor for the development and maintenance muscle-oriented disordered eating in in resistance training gym-goers. The direct relationship between heightened interoceptive sensibility and more muscle-oriented disordered eating in resistance training gym-goers may be explained by greater engagement in one's body through increased body image concerns. More awareness of one's body may also amplify an awareness of the body parts that are disliked or seen to be imperfect. In support of this possibility, our findings showed a strong mediating effect of appearance intolerance specifically.

We predicted that MD symptomology and APED usage would mediate the relationship between interoceptive sensibility and muscularity-oriented disordered eating (H2, H3, H4, & H5). We found that both MD symptoms (except for drive for size, (H3)) and APED usage partially mediated the positive direct association found between interoceptive sensibility and muscularity-oriented disordered eating. These findings support previous research showing increased interoceptive awareness in bodybuilders using anabolic steroids compared to non-using bodybuilders (Blouin & Goldfield, 1995; Kanayama et al., 2006). Therefore, increased APED use may not only enhance resistance training gym-goers susceptibility towards muscularity-oriented disordered eating, but also partially explain, in combination with increased MD symptomology, the positive direct association between interoceptive sensibility and muscularity-oriented disordered eating. Given that APED use can result in adverse marked changes in the body, it is plausible that interoceptive processes may be implicated in the onset and maintenance of APED usage and abuse (Maughan et al.,2018). For example, many APEDs are taken by bodybuilders to boost energy for workouts or to burn body fat (Hildebrandt, Varangis, & Lai, 2012), and are known to stimulate the autonomic nervous system, leading to increases in blood pressure, heart rate and metabolism (Maglione et al., 2005; Sánchez-Oliver, Grimaldi-Puyana, & Domínguez, 2019). These bodily sensations are arguably likely to shape the subjective feeling of supplement consumption. Previous research in drug addiction has demonstrated that interoceptive cues can function as strong and specific conditioned stimulus for drug use, provoking changes in central dopamine release and influencing drug seeking behaviour (Verdejo-Garcia, Clark, & Dunn, 2012), which therefore may explain why how heightened interoceptive awareness could lead to increased APED use. This may extend upon previous studies which have demonstrated increased body ownership to be associated with increased appearance enhancing supplement usage (Mussap & Salton, 2006). Previous research has also demonstrated that APED use was positively associated with eating disorder pathology (Hildebrandt, Harty, & Langenbucher, 2012). This supports previous research which has associated increased supplement use with increased ED symptomology across samples of both students (Nagata, Peebles, Hill, Gorrell, & Carlson, 2021; Ganson, Cunningham, Murray, & Nagata, 2022) and males in general (Hatoum & Belle, 2004). Therefore, it may be argued that heightened interoceptive awareness in muscularity dissatisfied gym-goers promotes engagement in APED use for the intent to influence one's physical appearance (Klimek & Hildebrandt, 2018), which in turn, promotes engagement in muscle-oriented disordered eating behaviours in pursuit for the idealised body.

We found that the drive for size did not relate to muscularity-oriented disordered eating, nor mediate the direct association between interoceptive sensibility and muscularity-oriented disordered eating. These findings suggest that drive for size alone does not significantly contribute to increased symptoms of muscularity-oriented disordered eating in resistance training gym-goers. Whereas, increased overall MD symptoms, as well as appearance intolerance and functional impairment, do relate to increased symptoms of muscularity-oriented disordered eating. These findings contradict previous research demonstrating that MD symptoms (including drive for size) correlated with increased eating disorder pathology in male gym-goers (Murray et al., 2012). This could be explained by the inclusion of female gym-goers within our sample, as previous research has demonstrated a preference towards a drive for leanness as opposed to drive for size in females (Cunningham et al., 2019).

We found that both increased appearance intolerance and functional impairment subscales related to increased muscularity-oriented disordered eating, and both partially mediated the direct association between interoceptive sensibility and muscularity-oriented disordered eating. Heightened interoceptive awareness in muscularity dissatisfied gym-goers promotes engagement in APED use for the intent to influence one's physical appearance (Klimek & Hildebrandt, 2018), which in turn, promotes engagement in muscle-oriented disordered eating behaviours in pursuit for the idealised body. This finding is novel and important given the shortage of studies assessing interoceptive sensibility and associated outcomes in resistance training gym-goers. Knowing the factors that maintain the relationship between interoceptive sensibility and muscularity-oriented disordered eating elucidates ideas for identifying or creating a robust intervention that addresses mediating factors in addition to muscularity-oriented disordered eating. For instance, providing educational content to gyms and leisure facilities to promote awareness of the risks of APED use and muscle-oriented disordered eating behaviours which can often be normalised within these environments (Hildebrandt, Varangis, & Lai, 2012).

These findings would suggest that any intervention (or a screening for prevention) need not focus on drive for size but more on body dissatisfaction and functional impairment.

**Limitations and Future Directions**

Our findings should be interpreted in light of several notable limitations. First, the research explored a non-clinical sample. It is unknown if variables in the present study function similarly among those with clinical levels of body image and eating disturbances. Additionally, we measured only legal APED usage. The generalisability of the present findings considering illegal APED use (e.g., steroids) is unknown. Since the use of illegal APEDs are illegal, we expected that any illegal APED use would have been servery self-underreported in our sample (Harvey, Parrish, van Teijlingen, & Trenoweth, 2021). Other empirical studies have taken urine samples to accurately measure illegal APED use across their participant sample (Sader, Griffiths, McCredie, Handelsman, & Celermajer, 2001). Another limitation includes the use of self-report measures. Participants may have been impacted by social desirability bias, underreporting symptoms in order to present themselves favourably (Tooze et al., 2004). Should underreporting of symptoms be present in our sample, we could arguably expect an enhanced association between increased interoceptive sensibility, MD, supplement use, and muscle-oriented disordered eating behaviours.

The novel findings from this present study lend itself to repetition and suggestions for future research. Future research that examines the relationship between interoceptive sensibility and muscularity-oriented disordered eating in illegal APED users is encouraged. The present study included subjective self-reported psychometric measures of interoceptive sensibility and muscle-oriented eating behaviour. Repetition by examining the present mediation model across other objective measures alongside self-reported measures of interoceptive sensibility and muscle-oriented eating behaviour would allow researchers to explore the proposed relationships with greater fidelity. For instance, using a muscular effort weight estimation task as a measure of interoceptive accuracy (similar to Murphy, Catmur, & Bird, 2018), and the ecological momentary assessment (Shiffman, Stone, & Hufford, 2008) may provide more accurate measure of what, how much and when people eat. Ecological momentary assessment has even been successfully adapted for use as an ED intervention (Norton, Wonderlich, Myers, Mitchell, & Crosby, 2003), so there is potential for further adaptation to populations with and at-risk of disordered eating towards muscle-oriented foods. Future research is warranted which distinguishes between drive for size and thinness-oriented eating behaviours amongst resistance training gym-goers, and how these eating behaviours may be associated with body awareness and whether any particular aspects of body awareness (e.g., certain body parts or functions) drive these associations. Findings from the current study have clinical implications for future prevention and intervention efforts targeting both MD and muscularity-oriented disordered eating in at-risk populations.

**Conclusions**

To conclude, the suggested model put emphasis on how increased interoceptive sensibility is associated with increased muscle-oriented disordered eating, although this effect is mediated by both MD and APED usage. Different from findings in ED populations, the direct relationship observed between heightened interoceptive sensibility and more muscle-oriented disordered eating in resistance training gym-goers may arguably be explained by greater engagement in one’s body through increased body image concerns, where a greater awareness of one’s body may also amplify an awareness of the body parts that are disliked or seen to be imperfect. The importance of both MD and APED usage in the development and maintenance of muscle-oriented disordered eating is also highlighted, and therefore arguably contribute to diagnostic criterion of both MD and muscle-oriented disordered eating.

# Chapter 4 Impact of restrictions during the COVID-19 pandemic on mood in gym members at-risk of muscle dysmorphia

## Abstract

This study examined the effect of gym closures on the exercise behaviour in those at-risk of MD and the wider UK exercise community during the COVID-19 pandemic, and whether a change in exercise behaviour was associated with mood disturbance, increased social media engagement during the lockdown. This study also considered the extent to which muscle dysmorphia (MD) symptomology was present amongst participants that reported exercising excessively using resistance. Participants were regular exercisers, either with or without gym memberships pre-pandemic, and aged between 18-65 years. Results indicated that increased MD symptoms predicted increased mood disturbance due to not being able exercise as normal, and these effects were enhanced for those with less access to home gym equipment and reduced perceptions of support from social media. We also found that the reduction in time spent exercising during lockdown was greater in gym members (38.1%) than non-gym members (2.5%), and greater in those with less access to home equipment to compensate for gym closures. Furthermore, the change in time spent exercising from pre to during lockdown predicted the severity of mood disturbance due to not being able to exercise as normal. It was concluded that despite gym closures being necessary to reduce virus transmission, such closures may have contributed toward increased mental health concerns in gym members at-risk of MD and the

wider exercise community, as well as the overall increase in mental health conditions observed during the lockdown.

# Introduction

In attempt to contain the widespread outbreak of a new Coronavirus (SARS-CoV-2), many governments enacted legislations which involved an immediate reduction in face-to face social interactions for business and recreation. In the United Kingdom (UK), on 23rd March 2020, the government imposed a national lockdown on all non-essential infrastructure (including schools, hospitality venues and retail stores). This meant that leisure centres, gyms (both indoor and outdoor) and other fitness facilities were forced to close (GOV.UK, 2020). Individual outdoor exercise was permitted once per day, sport participation was not permitted (only continued for athletes/teams under elite protocols) (GOV.UK, 2020).

In the same week, there was a sharp rise in Google search queries related to home gym equipment (Fig. 30). Relative to the mean of the previous 63 weeks and following 91 weeks, there was a 427-814% search query increase for the following search terms: ‘dumbbells’, ‘resistance bands’, ‘home workout’, ‘kettlebell’, and ‘home gym’. This sudden increase may be explained by exercisers attempting to minimise the impact of the lockdown on their exercise regime, by adapting their exercise regimes for the home, achieved via sourcing personal gym equipment, and engaging in online home workouts (Kaur, Singh, Arya, & Mittal, 2020). In addition to personal limitations from affordability and space, these home-based adaptations were hampered by ongoing issues with supply chains (Bataclan et al., 2021). Together with leisure facilities closures, these barriers may explain why within a sample of the UK general population, approximately 91% of all adults, and approximately 86% of younger adults (18-30 years old) reported engaging in below 30 minutes of moderate or high intensity physical activity in the first week of lockdown (Fancourt, Bu, Mak, & Steptoe, 2020). These lockdown sedentariness rate differ substantially from the Health Survey for England 2018, where approximately 27% of adults, and approximately 22% of young adults (16-34 years old) reported engaging in below 30 minutes of moderate or vigorous physical activity per week (NHS Digital, 2019). This extreme decline in physical activity during lockdown was not limited to the UK, it also was observed in many other countries during national lockdowns (Stockwell et al., 2021). For example, a study on the COVID-19-related lockdowns and enforced regulations for social distancing in Germany found exercise levels declined sharply and significantly, such that approximately 60% of people remained or became inactive, with 31% reducing their exercise considerably (or completely stopped exercising) compared to a 'normal week' (Mutz & Gerke, 2021). However, only 22.4% of active Canadians became less active, while 40.3% actually became more active (Lesser & Nienhuis, 2020). Similarly, in New Zealand, moderately active individuals pre-lockdown, reported higher overall physical activity, vigorous and moderate intensity physical activity during lockdown compared to pre-lockdown (Hargreaves et al., 2021). It is unclear why Canadians and New Zealanders were, in general, more physically active during lockdown. Despite a few exceptions, most studies demonstrated that containment and mitigation policies resulted in (forced) sedentariness for many (Stockwell et al., 2021; Wilke et al., 2021).

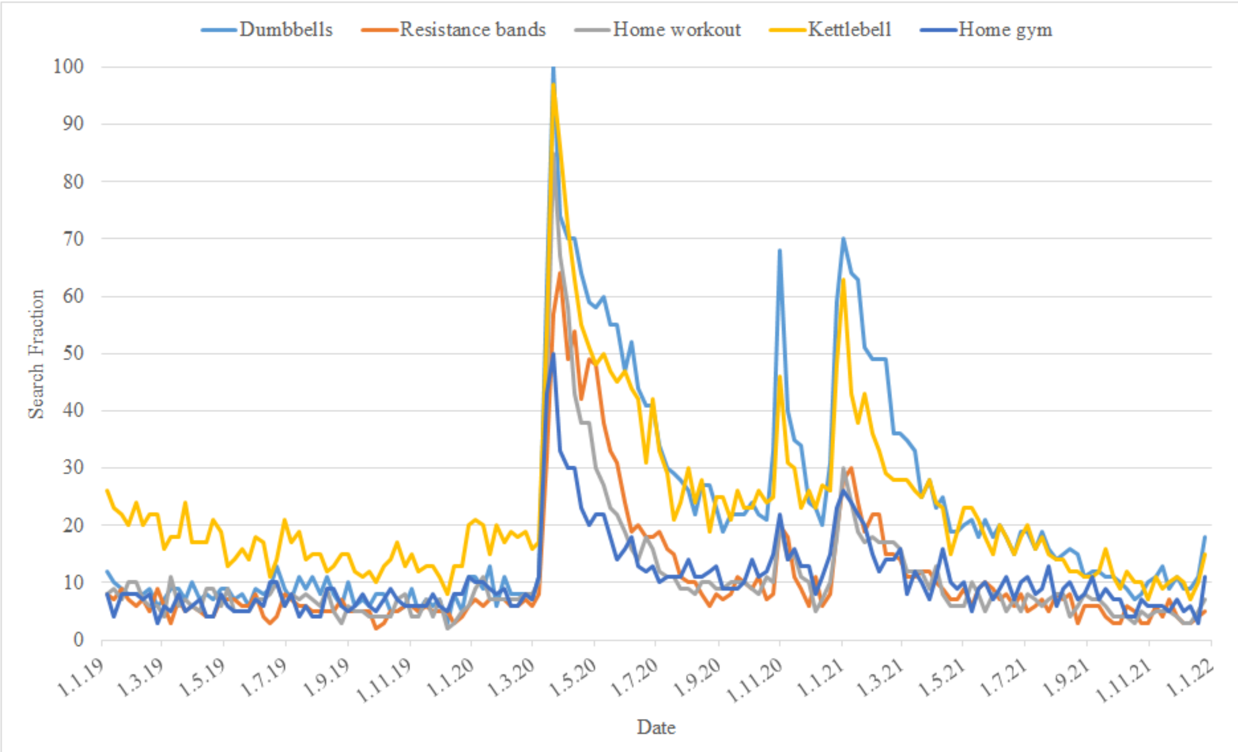



Figure 30. Relative search volume for exercise equipment and home workout from January 2019 to January 2022 in the UK. Note. Google Trends is a Web-based free tracking system of Google search volumes. Google Trends algorithmics normalise data for the overall number of searches on a scale from 0 (search volume <1% of the peak volume) to 100 (peak of popularity), presenting them as a weekly relative search volume (RSV). RSV values are by definition, as presented in the y-axis (Fig 1), always less than 100, and display a proportion compared with the highest search volume. This approach corrects results for population size and Internet access, both of which increased during the study period.

Exercise is commonly associated with enhanced physical health, as it is known to provide protection against the stress of disease (Yan & Spaulding, 2020) and optimise the body's immune functioning, which are important protective factors towards physical illness (Laddu, Lavie, Phillips, & Arena, 2021). Furthermore, exercise is known to improve mental health including mood state and self-esteem (Blair, Kohl, Gordon, & Paffenbarger Jr, 1992; Raglin, 1990; Peluso & De Andrade, 2005). Therefore, despite Government imposed lockdown measures being necessary to diminish virus transmission (Chu et al., 2020), maintaining such restrictions and the consequent fewer opportunities to engage in exercise (Chen et al., 2020), has resulted in increased levels of anxiety and depression (Brooks et al., 2020) and negative mood (Ingram, Maciejewski, & Hand, 2020). Also, in other countries a reduction in physical activity was found to have a severely negative impact on psychological health and well-being (Stockwell et al., 2021).

Mental health including body image concerns and compensatory behaviours related to eating and exercising are also heavily influenced by (social) media (Robinson et al., 2017; Saiphoo & Vahedi, 2019;. While some of these influences are somewhat higher in younger age groups and in females (Saiphoo & Vahedi, 2019), they are also evident in male populations, who pursue a lean and muscular body ideal (Griffiths, Murray, Krug, & McLean, 2018). This drive for muscularity is considered a risk factor for developing MD (Robert, Munroe-Chandler, & Gammage, 2009). MD is a subtype of body dysmorphic disorder (American Psychiatric Association, 2013), characterised by an obsessive concern for one's physical appearance, particularly one's muscularity (Pope Jr, Gruber, Choi, Olivardia, & Phillips, 1997). Body dissatisfaction is the main feature of MD (Olivardia, Pope Jr, & Hudson, 2000), where individuals with MD experience feelings of shame and embarrassment about their bodies, resulting in adopting avoidance behaviours that reach clinical levels (Strelan & Hargreaves, 2005). For individuals who use exercise to escape from stress (such as those with MD), this may result in spiraling further into a pattern of avoidance and escape, creating a dangerous circular causal relationship between exercise and stress. Increased exposure to stigmatising social media content in relation to dangers of increased body weight may have contributed to increased body shaming (LePage & Crowther, 2010) and pressurised men to increase muscularity and/or leanness (Fatt, Fardouly, & Rapee, 2019) during the lockdown. This increased exposure stigmatising social media may also provide some explanation towards the observed increase in body image disturbance and disordered eating during the lockdown amongst the general population (Maltby & Day, 2001) and gym members (Trott et al., 2021).

For individuals motivated to exercise for appearance-related reasons, physical and mental health benefits tend not to be experienced (Strelan & Hargreaves, 2005). Research has demonstrated that exercising for weight change, body tone and attractiveness reasons are related to disordered eating (Furnham, Badmin, & Sneade, 2002), body dissatisfaction (LePage & Crowther, 2010), reduced self-esteem (Strelan & Hargreaves, 2005), and diminished psychological well-being (Maltby & Day, 2001). These deleterious effects can be further exacerbated by exercising in gyms, where gym members have been found to be more likely to experience body image disturbance and disordered eating compared to non-gym members (Prichard & Tiggemann, 2008; Stapleton, McIntyre, & Bannatyne, 2016; Jankauskienė, Kardelis, & Pajaujienė, 2007). In light of these findings, it may be argued that gym members could be disproportionally affected by the forced closure of gyms during the lockdown, considering both the existing susceptibility towards body image disturbance and disordered eating development in gym members compared to non-gym members, and the limited ability for gym members to maintain and/or adjust their regular exercise regimen independent from the gym.

Regardless of the physical activity changes, there is substantial evidence towards a decline in mental health and wellbeing in the UK during the COVID-19 pandemic (GOV.UK, 2022). Various studies have reported levels of anxiety, depression, and stress to all be higher than expected at the end of March and beginning of April 2020 in the UK (Fancourt, Bu, Mak, & Steptoe, 2020; Fancourt, Steptoe, & Bu, 2021; Shelvin et al., 2020; Jia et al., 2020).

Globally, mental health and wellbeing concerns have also been evidenced during the COVID-19 pandemic. A recent meta-analysis found a prevalence of 25% anxiety and 28% depression within the general Chinese population (Ren et al., 2020), while another reported that 29.6% of people experienced stress, 31.9% anxiety and 33.7% depression, with relatively higher levels in younger age groups (21–40 years) (Salari et al., 2020; Shah et al., 2021). An increase in stress, depression and anxiety during the COVID-19 outbreak has been further associated with a rise in disordered eating (Touyz, Lacey, & Hay, 2020; Schlegl, Maier, Meule, & Voderholzer, 2020) and more negative body image in both men and women (Swami, Horne, & Furnham, 2021; Ahuja, Khandelwal, & Banerjee, 2021). Early explanations suggest that the rise in body image concern is possibly due to changes in daily routines which impede adaptive body image coping mechanisms (e.g., exercise) and increase maladaptive coping, enhanced concerns toward weight and/or shape changes, and frequency of negative body ruminations (Cooper et al., 2022).

Understanding the changes in physical activity and social media use during lockdown is important not only for those at-risk of body image disturbance and other mental health outcomes associated with these behaviours, but for supporting development of public health interventions in specific populations (such as physical activity promotion and interventions to decrease social media use), should future lockdowns be imposed, a similar pandemic situation and/or during the return to living with limited restrictions (Sallis, Adlakha, Oyeyemi, & Salvo, 2020). Therefore, the aim of the current study was to examine changes in both physical activity, social media use, and mood disturbance during, versus, and before the COVID-19 pandemic lockdown in the UK exercise population. Additionally, this study sought to examine the effects of gym closures on the ability of gym members and non-gym members to cope with the pressures to exercise and to 'transform' their body during the lockdown. Further, we assess whether having access to home equipment enabled exercisers to engage in exercise during the lockdown.

The following hypotheses were made:

H1 Increased MD symptoms, increased exercise change, reduced quantity of home gym equipment and increased social media engagement in gym members at-risk of MD would be associated with increased current mood disturbance.

H2 Decrease in exercise from before to during lockdown would be associated with increased mood disturbance, and that this disturbance would be more pronounced for gym members compared to non-gym members.

H3 Lack of access to home gym equipment would be associated with greater reductions in exercise and increased mood disturbance.

H4 More frequent use of social media would be associated with greater exercise-related mood disturbance.

# Materials and Methods

## Participants

Adults (18- 65 years) living in the UK who exercise were invited to take part in a study on the impact of lockdown on mood disturbance and exercise behaviour. Participants were recruited online between June and September 2020 using advertisements shared on social media by the research team. The sample size was decided a priori in order to have a power of 0.8 and reveal an effect size of 0.3 in a multiple regression analysis (calculated with G*Power) (Cohen, 1983). A total of 542 unique respondents entered the survey between 3rd June and 28th September

2020 (All UK gym closures commenced on 23rd March 2020 until at least 25th July 2020, which was the earliest date for gyms to reopen). We only used data from those who had answered the set of questions about how they had been affected by the COVID-19 lockdown. To screen for multivariate outliers among predictor variables, we used Mahalanobis distances. Multiple regression analysis was used to generate Mahalanobis distances, which follows a Chi-square ($\chi^2$) distribution, with degrees of freedom equivalent to the number of independent variables in the regression (Tabachnick, Fidell, & Ullman, 2007). In this instance, there were 116 multivariate outliers. Subsequent examination of the cases revealed that the individual response pattern across the variables were sufficiently abnormal to be deemed illegitimate respondents. This left a total of 426 respondents (185 men, 203 women, age: $M$ = 28.75, $SD$ = 8.23; plus 39 respondents for whom age and sex data were missing) for this study.

The study received ethical approval from the Science and Health Ethics Sub Committee, University of Essex. Prior to participation, participants provided electronic informed consent.

## Materials and Procedure

Participants completed an online retrospective survey supported by Qualtrics (https://www.qualtrics.com), which included general demographic information (e.g., age, sex, exercise behaviours and social media use). We also included questions for participants to indicate whether they had a gym membership, the type and amount of home exercise equipment they owned and used, and the extent to which being able to exercise the way they prefer contributes to their happiness ('How much of your wellbeing / happiness depends on your ability to exercise in the way that you prefer?'). Those who had gym memberships, reported excessively exercising (an average exercise duration ≥ 6hrs per week pre-lockdown), and stated exercising regularly with resistance for at least 6 months prior to the lockdown, were asked to complete the Muscle Dysmorphic Disorder Inventory (MDDI) (Hildebrandt, Langenbucher, & Schlundt, 2004) to determine the extent of MD symptomatology within our sample of exercisers.

## Muscle Dysmorphia

To assess severity of MD within our sample, participants were presented with the MDDI (Hildebrandt, Langenbucher, & Schlundt, 2004). The MDDI questionnaire consists of 13 self-reported statements, items are rated on a 5-point scale, ranging from “never” to “always”. Total scores range from 13 to 65, with higher scores reflecting greater MD psychopathology. The questionnaire is not a diagnostic tool but is designed to correspond to the proposed diagnostic criteria (Pope Jr, Gruber, Choi, Olivardia, & Phillips, 1997). The MDDI has been widely used to identify individuals displaying MD related symptoms (Klimek, Murray, Brown, Gonzales IV, & Blashill, 2018; Pope Jr et al., 1997; Santarnecchi & Dèttore, 2012; Zeeck et al., 2018). The MDDI has a proposed cut-off score of >39 for individuals “at risk” of MD (Varangis, Folberth, Hildebrandt, & Langenbucher, 2012, which has been used in previous research (Lechner, Gill, Drees, Hamady, & Ludy, 2019; Longobardi, Prino, Fabris, & Settanni, 2017; Zeeck et al., 2018). The MDDI has demonstrated good reliability, (Cronbach's $\alpha = .77–.85$; test–retest reliability $r = .81–.87$) and construct validity (Hildebrandt, Langenbucher, & Schlundt, 2004).

## Changes in Exercise

To compare exercise engagement at the beginning of the COVID-19 pandemic with the usual level of exercise from the time before this outbreak, participants were first retrospectively asked: ‘Before the corona virus outbreak, on average, how many hours of exercise were you doing each week?' and second, 'Over the past week, how many hours of exercise have you done?'.  Respondents indicated their exercise duration in hours per week on a 30-point rating scale (ranging from 0 to 30 hrs per week). These answers were used to estimate the change in exercise engagement that was due to COVID-19-related policies of containment.

## Changes in Mood

To compare mood changes (anxiety, depression, and frustration) at the beginning of the COVID-19 pandemic with mood before the pandemic, participants were first asked: 'For the first 2 weeks of lockdown, to what extent have you felt the following emotions due to not being able to exercise as normal:'(anxious, depressed, and frustrated) and second, 'Today, to what extent do you feel the following emotions due to not being able to exercise as normal:' (anxious, depressed, and frustrated). Respondents indicated their mood for each emotion on a 100-point rating scale ranging from 0 (not at all) to 100 (extremely). These answers were used to estimate the change in mood that was due to not being able to exercise as normal for prolonged periods of time.

## Social Media

To assess changes in social media use, participants were asked: 'Has your social media use changed since the corona virus outbreak?'. Respondents indicated their change in use on a 100-point rating scale ranging from 0 (extremely decreased) to 100 (extremely increased). To measure changes in affect from social media use, participants were asked: 'In general, how has using social media made you feel during the corona virus outbreak?'. Respondents indicated their feeling on a 100-point rating scale ranging from 0 (extremely negative) to 100 (extremely positive). To measure the extent social media supports exercise regimes during the lockdown, participants were asked: 'How supportive has social media been towards your exercise regime during the corona virus outbreak?'. Respondents indicated their level of supportiveness on a 100-point rating scale ranging from 0 (extremely unsupportive) to 100 (extremely supportive). To measure the extent participants felt pressured to exercise and transform their body during the lockdown due to social media, participants were asked: 'How pressured do you feel to exercise during the corona virus outbreak due to social media?', and 'How pressured do you feel to transform your body during the corona virus outbreak due to social media?'. Respondents indicated their level of perceived pressure on a 100-point rating scale ranging from 0 (not pressured at all) to 100 (extremely pressured).

## Data Analysis

Firstly, a series of planned multiple linear regression analyses were conducted to explore the associations between MD symptoms, exercise change, access to home equipment, demographic factors, and muscle dysmorphic symptoms on changes in mood (anxiety, depression, and frustration) due to not being able to exercise as normal. Secondly, a planned two-way mixed-measures ANOVA assessed changes in exercise engagement from before to during lockdown, and the effects of gym membership and home equipment on such changes. For this purpose, our home equipment measure was transformed into a nominal variable by median-splitting participants into two groups (those with 1 or fewer pieces of equipment; those with 2 or more pieces of equipment). Group averages were then subjected to a Bonferroni-adjusted independent samples t-test to assess differences between the groups. Finally, a planned multiple independent sample t-tests were performed for comparison between gym members and non-gym members. Data preparation and analyses were conducted using the IBM SPSS Statistics version 25. The false discovery rate method of correction for multiple comparisons (Benjamini & Hochberg, 1995) was applied to correlation results, results that did not survive correction are not reported.

# Results

## Muscle Dysmorphia

In the MDDI, a score >39 indicated that subjects were at a high risk of developing MD. In our sample of 176 gym members that completed the MDDI, 22.2% (n = 39) were at a high risk of developing MD. Our sample had an overall MDDI mean score of 32.52 (SD=9.01).

Current anxiety due to not being able to exercise as normal was significantly predicted by the collective effect of MD symptoms, exercise change, home gym equipment, at the start of lockdown, social media usage, social media affect, social media support, social media exercise pressure, social media body pressure, age, and sex ($F$ (11,136) = 13.23, $p$ = <.001, $R^2$ = .478) (see Table 8). Gym members at risk of MD estimated their current anxiety equal to -10.85 + 0.34 (MD total) + 0.34 (Exercise change) - 0.91 (Home equipment) + 0.41 (Anxiety start of lockdown) + .004 (Social Media Usage) + .068 (Social Media Affect) - 0.20 (Social Media Support) + 0.24 (Social Media Exercise Pressure) - 0.01 (Social Media Body Pressure) - 0.17 (Age) + 12.29 (Sex). Therefore, for every 1 unit increase in MD symptomology, self-reported current anxiety increased by 0.81%.

Table 8 Multiple regression: Impact of muscle dysmorphia on current anxiety not being able to exercise as normal.

| Step | Predictors | β | $R^2$ |
|---|---|---|---|
| 1 | MD total | 1.57** | .44 |
| 2 | MD total | .81* | .72 |
| | Exercise Change | .34* | |
| | Home Gym Equipment [a] | -.91 | |
| | Anxiety start of lockdown | .41** | |
| | Social Media Use | .04 | |
| | Social Media Affect | .07 | |
| | Social Media Support | -.20* | |
| | Social Media Exercise Pressure | .24* | |
| | Social Media Body Pressure | -.01 | |
| | Age | -.17 | |
| | Sex [b] | 12.23* | |

* $p < .05$, ** $p < .001$

*Note.* [a] Home gym equipment is coded 0 = ≤ 1 pieces of equipment, 1 = ≥ 2 pieces of equipment; [b] Sex is coded as 1 = Male, 2 = Female.

Current depression due to not being able to exercise as normal was significantly predicted by the collective effect of MD symptoms, exercise change, home gym equipment, depression at the start of lockdown, social media usage, social media affect, social media support, social media exercise pressure, social media body pressure, age, and sex ($F$ (11,136) = 17.66, $p$ = <.001, $R^2$ = .588) (see Table 9). Gym members at risk of MD estimated their current depression equal to -9.34 + 0.58 (MD total) + 0.29 (Exercise change) - 1.44 (Home equipment) + 0.50 (Depression start of lockdown) + .001 (Social Media Usage) + 0.05 (Social Media Affect) -0.25 (Social

Media Support) + 0.19 (Social Media Exercise Pressure) + 0.01 (Social Media Body Pressure) - 0.14 (Age) + 10.80 (Sex). Therefore, for every 1 unit increase in MD symptomology, self-reported current anxiety increased by 0.58%.

Table 9 Multiple regression: Impact of muscle dysmorphia on current depression not being able to exercise as normal.

| Step | Predictors | β | $R^2$ |
|---|---|---|---|
| 1 | MD total | 1.41** | .40 |
| 2 | MD total | .58* | .77 |
| | Exercise Change | .29 | |
| | Home Gym Equipment [a] | -1.44* | |
| | Depression start of lockdown | .50** | |
| | Social Media Use | .001 | |
| | Social Media Affect | .05 | |
| | Social Media Support | -.25* | |
| | Social Media Exercise Pressure | .19* | |
| | Social Media Body Pressure | .01 | |
| | Age | -.14 | |
| | Sex [b] | 10.8* | |

* $p < .05$, ** $p < .001$

*Note.* [a] Home gym equipment is coded 0 = ≤ 1 pieces of equipment, 1 = ≥ 2 pieces of equipment; [b] Sex is coded as 1 = Male, 2 = Female.

Current frustration due to not being able to exercise as normal was significantly predicted by the collective effect of MD symptoms, exercise change, home gym equipment, frustration at the start of lockdown, social media usage, social media affect, social media support, social media exercise pressure, social media body pressure, age, and sex ($F$ (11,136) = 9.32, $p$ = <.001, $R^2$ =

.430) (see Table 10). Gym members at risk of MD estimated their current anxiety equal to -6.67 + 0.53 (MD total) + 1.15 (Exercise change) – 0.71 (Home equipment) + 0.39 (Frustration start of lockdown) + 0.13 (Social Media Usage) + - 0.01 (Social Media Affect) – 0.25 (Social Media Support) + 0.11 (Social Media Exercise Pressure) + 0.08 (Social Media Body Pressure) + 0.17 (Age) + 4.79 (Sex). Therefore, for every 1 unit increase in MD symptomology, self-reported current anxiety increased by 0.53%.

Table 10 Multiple regression: Impact of muscle dysmorphia on current frustration not being able to exercise as normal.

| Step | Predictors | β | $R^2$ |
|---|---|---|---|
| 1 | MD total | 1.38** | .37 |
| 2 | MD total | .53 | .66 |
| | Exercise Change | 1.15* | |
| | Home Gym Equipment [a] | -.71 | |
| | Frustration start of lockdown | .39** | |
| | Social Media Use | .13 | |
| | Social Media Affect | -.01 | |
| | Social Media Support | -.25* | |
| | Social Media Exercise Pressure | .11 | |
| | Social Media Body Pressure | .08 | |
| | Age | .17 | |
| | Sex [b] | 4.79 | |

* $p < .05$, ** $p < .001$

*Note.* [a] Home gym equipment is coded 0 = ≤ 1 pieces of equipment, 1 = ≥ 2 pieces of equipment; [b] Sex is coded as 1 = Male, 2 = Female.

Taken together, regression analyses indicated that MD symptoms independently predicted all measured dimensions of current mood (increases in anxiety, depression, frustration), demonstrating that increased MD symptoms levels negatively affect mood. In addition, we found that less access to home equipment independently predicted higher depression, an increased change in exercise engagement independently predicted greater present anxiety and frustration. Additionally, perceptions of social media being unsupportive towards exercise routine predicted all measured dimensions of current mood, perceptions of social media being pressuring towards exercise routine predicted anxiety and depression. Furthermore, we found that sex independently predicted greater current anxiety and depression. Finally, current mood was also predicted by mood at the start of lockdown, showing stability in self-report across past and present mood states.

## Changes in Mood

Multiple linear regression indicated that current anxiety due to not being able to exercise as normal was significantly predicted by the collective effect of exercise change, home equipment, gym membership, anxiety at the start of lockdown, age, sex and being an excessive exerciser ($F(7,379) = 50.80$, $p = <.001$, $R^2 = .458$) (see Table 11). Exercisers' estimated current anxiety due to not being able to exercise as normal was equal to 21.37 + 0.87 (Exercise change) - 5.611 (Home equipment) -4.63 (Gym membership) + 5.33 (Excessive exerciser) + 0.58 (Anxiety start of lockdown) – 0.18 (Age) + 3.16 (Sex). Therefore, for every 1 hour per week of less exercise compared to pre-lockdown, self-reported current anxiety increased by 0.87%. Those with 1 piece of home gym equipment or less reported 5.61% higher current anxiety levels than participants with 2 or more pieces of home gym equipment. Furthermore, for every 1% increase of self-reported anxiety at the start of lockdown, self-reported estimates of current anxiety increased by 0.58%.

Table 11 Multiple regression: Impact of exercise change on current anxiety not being able to exercise as normal.

| Step | Predictors | β | $R^2$ |
|---|---|---|---|
| 1 | Exercise Change | 1.87** | .075 |
| 2 | Exercise Change | 0.87* | .458 |
| | Home Gym Equipment [a] | -5.61* | |
| | Gym Membership [b] | -4.63 | |
| | Excessive Exerciser [c] | 5.33 | |
| | Anxiety start of lockdown | 0.58** | |
| | Age | -0.18 | |
| | Sex [d] | 3.16 | |

* $p < .05$, ** $p < .001$

*Note.* [a] Home gym equipment is coded 0 = ≤ 1 pieces of equipment, 1 = ≥ 2 pieces of equipment; [b] Gym membership is coded as 1 = gym member, 2 = non-gym member; [c] Excessive exerciser is coded as 0 = non gym member and/or average exercise < 6hrs per week pre-lockdown and/or did not exercise regularly with resistance for at least 6 months, 1 = gym members with average exercise duration ≥ 6hrs per week pre-lockdown and exercising regularly with resistance for at least 6 months; [d] Sex is coded as 1 = Male, 2 = Female.

Current depression due to not being able to exercise as normal was significantly predicted by the collective effect of exercise change, home equipment, gym membership, depression at the start of lockdown, age, sex and being an excessive exerciser ($F$ (7,379) = 50.80, $p$ = <.001, $R^2$ =

.484) (see Table 12). Exercisers' estimated current depression was equal to 17.72 + 0.82 (Exercise change) -5.96 (Home equipment) – 4.83 (Gym membership) + 3.38 (Excessive exerciser) + 0.61 (Depression start of lockdown) + 0.64 (Age) + 1.38 (Sex). Therefore, for every 1 hour per week of less exercise compared to pre-lockdown, self-reported current depression increased by 0.82%. Gym members estimated their current depression to be 4.83% higher than non-gym members. Those with 1 piece of home gym equipment or less reported feeling 5.96% more depressed than participants with 2 or more pieces of home gym equipment. Finally, for every 1% increase of self-reported depression at the start of lockdown, self-reported estimates of current depression increased 0.61%.

Table 12 Multiple regression: Impact of exercise change on current depression not being able to exercise as normal

| Step | Predictors | β | $R^2$ |
|---|---|---|---|
| 1 | Exercise Change | 1.64** | .060 |
| 2 | Exercise Change | 0.82* | .484 |
| | Home Gym Equipment [a] | -5.96* | |
| | Gym Membership [b] | -4.83* | |
| | Excessive Exerciser [c] | 3.38 | |
| | Depression start of lockdown | .611** | |
| | Age | 0.64 | |
| | Sex [d] | 1.38 | |

* $p \leq .05$, ** $p \leq .001$

*Note.* [a] Home gym equipment is coded 0 = ≤ 1 pieces of equipment, 1 = ≥ 2 pieces of equipment; [b] Gym membership is coded as 1 = gym member, 2 = non-gym member; [c] Excessive exerciser is coded as 0 = non gym member and/or average exercise < 6hrs per week pre-lockdown and/or did not exercise regularly with resistance for at least 6 months, 1 = gym members with average exercise duration ≥ 6hrs per week pre-lockdown and exercising regularly with resistance for at least 6 months; [d] Sex is coded as 1 = Male, 2 = Female.

Current frustration due to not being able to exercise as normal was significantly predicted by the collective effect of exercise change, home equipment, gym membership, frustration at the start of lockdown, age, sex and being an excessive exerciser ($F$ (7,379) = 42.43, $p$ = <.001, $R^2$ = .439) (see Table 13). Exercisers' estimated current frustration was equal to 28.01 + 1.27 (Exercise change) - 4.03 (Home equipment) – 6.27 (Gym membership) + 6.77 (Excessive exerciser) + 0.54 (Frustration start of lockdown) + 0.09 (Age) -1.21 (Sex). Therefore, for every 1 hour per week of less exercise compared to pre-lockdown, self-reported current frustration increased by 1.27%. Gym members estimated their current frustration to be 6.27% higher than non-gym members, and excessive exercisers estimated their current frustration to be 6.77% higher than non-excessive exercisers. Furthermore, for every 1% increase of self-reported frustration at the start of lockdown, self-reported estimates of current frustration increased by 0.54%.

Table 13 Multiple regression: Impact of exercise change on current frustration not being able to exercise as normal.

| Step | Predictors | β | $R^2$ |
|---|---|---|---|
| 1 | Exercise Change | 2.30** | .099 |
| 2 | Exercise Change | 1.27** | .439 |
| | Home Gym Equipment [a] | -4.03 | |

| | |
|---|---|
| Gym Membership [b] | -6.27* |
| Excessive Exerciser [c] | 6.77* |
| Frustration start of lockdown | 0.54** |
| Age | 0.94 |
| Sex [d] | -1.21 |

* $p < .05$, ** $p < .001$

*Note.* [a] Home gym equipment is coded 0 = ≤ 1 pieces of equipment, 1 = ≥ 2 pieces of equipment; [b] Gym membership is coded as 1 = gym member, 2 = non-gym member; [c] Excessive exerciser is coded as 0 = non gym member and/or average exercise < 6hrs per week pre-lockdown and/or did not exercise regularly with resistance for at least 6 months, 1 = gym members with average exercise duration ≥ 6hrs per week pre-lockdown and exercising regularly with resistance for at least 6 months; [d] Sex is coded as 1 = Male, 2 = Female.

Taken together, regression analyses indicated that lockdown-induced reduction in exercise independently predicted all measured dimensions of current mood (increases in anxiety, depression, frustration), demonstrating that decreases in physical activity levels negatively affect mood. In addition, we found that gym membership (without being able to access gyms) independently predicted greater depression and more frustration, less access to home equipment independently predicted higher anxiety and depression, and previously engaging in excessive exercising independently predicted greater present frustration. Finally, current mood was also predicted by mood at the start of lockdown, showing stability in self-report across past and present mood states.

## Gym Member Mood Change

Among those with gym memberships pre-lockdown (n=250), the average change in time spent exercising per week positively correlated with depression ($r(250) = .184$, $p = .004$), frustration ($r(250) = .276$, $p < .001$), and anxiety ($r(250) = .257$, $p < .001$) – where a reduction in exercise is defined as an increase exercise change, and an increase in mood disturbance (anxiety, frustration, or depression) due to not being able to exercise as normal is defined as an increase in mood disturbance on each of these measures (See Table 14 for descriptive statistics).

Table 14 Means, standard deviations, and Pearson's correlations for 3 mood disturbance measures (current anxiety, frustration, and depression) not being able to exercise as normal and exercise change in gym members (n=250) and non-gym members (n=176).

| | M | *SD* | Exercise Change |
|---|---|---|---|
| Gym Members | | | |
| Exercise Change | 1.84 | 4.64 | - |
| Anxiety | 41.42 | 30.61 | .257** |
| Frustration | 49.54 | 32.75 | .276** |
| Depression | 38.50 | 29.76 | . 184* |
| Non-gym Members | | | |
| Exercise Change | 0.34 | 4.50 | - |
| Anxiety | 32.03 | 29.16 | .217* |
| Frustration | 30.16 | 27.53 | .257* |
| Depression | 37.48 | 31.21 | . 245* |

* $p < .05$, ** $p < .001$

## Social Media

For Exercise Changes (where a reduction in exercise is defined as an increase exercise change), Pearson's correlations indicated significant associations between affect from using social media between increased time spent exercising per week during the lockdown ($r(412) = -.10$, $p = .039$), there was no significant correlation between perceptions of social media use and exercise change ($r(412) = .01$, $p > .05$), and also for perceptions of social media support and exercise change ($r(382) = -.07$, $p > .05$). Further Pearson's correlations indicated associations between increased pressure to exercise during the lockdown from social media positively correlated with a reduction in time spent exercising per week during the lockdown ($r\ (370) = .11$, $p = .029$). Also, social media pressure to 'transform' their body during lockdown positively correlated with a reduction in time spent exercising per week during the lockdown ($r\ (370) = .15$, $p = .003$).

For mood changes, Pearson's correlations indicated significant positive associations between the social media use and anxiety ($r\ (412) = .15$, $p = .003$), frustration ($r\ (412) = .12$, $p = .018$), but not for depression ($r\ (412) = .07$, $p > .05$). Also, further Pearson's correlations indicated significant negative associations between social media affect during the lockdown and perceptions of anxiety ($r\ (412) = -.12$, $p = .016$), frustration ($r\ (412) = -.15$, $p = .002$), and depression ($r\ (412) = -.16$, $p = .001$). There were no significant associations between perceptions of social media support and perceptions of anxiety ($r\ (382) = -.04$, $p > .05$), frustration ($r\ (382) = -.06$, $p > .05$), and depression ($r\ (382) = -.05$, $p > .05$). However, there were significant positive associations between pressure to exercise during the lockdown from social media and perceptions of anxiety ($r\ (370) = .34$, $p < .001$), frustration ($r\ (370) = .34$, $p < .001$), and depression ($r$ (370) = .30, $p$ < .001). Furthermore, there were significant positive associations between pressure to 'transform' their body during lockdown from social media and perceptions of anxiety ($r$ (370) = .38, $p$ < .001), frustration ($r$ (370) = .38, $p$ < .001), and depression ($r$ (370) = .35, $p$ < .001).

## Exercise Behaviour

Overall, the estimated average number of hours spent exercising per week declined by approximately 1 hour 50 minutes from before lockdown ($M$ = 6.81, $SE$ = 0.24) to during lockdown ($M$ = 5.30, $SE$ = 0.22), ($F$ (1, 442) = 44.55, $p$ <.001, $\eta_p^2$ = .095).

While there was no significant main effect of gym membership ($F$ (1, 442) = .14, $p$ = .70, $\eta_p^2$ < .001), a significant interaction between gym membership and exercise ($F$(1, 442) = 36.17, $p$ < .001 , $\eta_p^2$ = .079) indicated that exercise decline was greater in gym members than in non-gym members. Bonferroni-corrected estimated marginal means of the effects of exercise at each level of gym membership indicted that gym members spent more hours exercising per week before lockdown ($M$ = 7.57, $SE$ = 0.30) than during lockdown ($M$ = 4.69, $SE$ = 0.28), ($F$ (1, 442) = 103.72, $p$ < .001, $\eta_p^2$ = .20). However, mean hours spent exercising per week did not change for non-gym members (before: $M$ = 6.05, $SE$ = 0.37; during: $M$ = 5.90, $SE$ = 0.35) ($F$ (1, 442) = 0.18, $p$ = .673, $\eta_p^2$ < .001).

There was a significant main effect of home equipment on average number of hours spent exercising per week ($F$ (1, 442) = 15.69, $p$ <.001, $\eta_p^2$ = .036). Those with ≤ 1 piece of home equipment spent fewer hours exercising per week ($M$ = 5.26, $SE$ = 0.25) compared to those with ≥ 2 pieces of home equipment ($M$ = 6.85, $SE$ = 0.31). There was also a significant interaction between home equipment and exercise (*F* (1, 442) = 4.13, *p* =.04, $\eta_p^2$ = .01), indicating that detrimental effect of the lockdown on average number of hours spent exercising per week was greater for those with ≤ 1 piece than those with ≥ 2 pieces of home equipment. Bonferroni-corrected estimated marginal means of the effects of exercise at each level of home equipment indicted that the mean hours spent exercising per week for those with ≤ 1 piece of home equipment was higher before lockdown (*M* = 6.25, *SE* = 0.30) than during lockdown (*M* = 4.27, *SE* = 0.28) (*F*(1, 442) = 48.20, *p* < .001, $\eta_p^2$ = .10). While the same was true for those with ≥ 2 pieces of home equipment (before: *M* = 7.38, *SE* = 0.37; during: *M* = 6.32, *SE* = 0.35), (*F*(1, 442) = 8.88, *p* = .003, $\eta_p^2$ = .02), the proportional change in mean hours spent exercising (14.4% reduction) was less than half compared to the change seen in those with less home equipment (31.7% reduction).

There was no statistically significant interaction between gym membership, home equipment and exercise (*F* (1, 442) = .33, *p* = .57, $\eta_p^2$ = .001). However, Bonferroni-corrected estimated marginal means of the effects of exercise at each level of gym membership and home equipment indicted that the aforementioned effects of home equipment on exercise reduction was specific to gym members, for whom exercise reduced by 49.4% from before (*M* = 6.50, *SE* = 0.41) to during lockdown (*M* = 3.29, *SE* = 0.39), (*F* (1, 442) = 67.71, *p* < .001, $\eta_p^2$ = .14) when they had access to ≤ 1 piece of home equipment, and by 29.5% from before (*M* = 8.64, *SE* = 0.43) to during lockdown (*M* = 6.09, *SE* = 0.41), (*F*(1, 442) = 38.77, *p* < .001, $\eta_p^2$ = .08) when they had access to ≥ 2 pieces of home equipment. For non-gym members with ≤ 1 piece of home equipment exercise did not change from before (*M* = 5.99, *SE* = 0.43) to during lockdown (*M* = 5.25, *SE* = 0.41), (*F*(1, 442) = 3.20, *p* = .07, $\eta_p^2$ = .008), and the same was true for non-gym members with ≥ 2 pieces of home equipment (before: *M* = 6.11, *SE* = 0.60; during: *M* = 6.56, *SE* = 0.57), ($F(1, 442) = 0.59$, $p = .44$, $\eta_p^2 = .001$).

Taken together, these results suggest gym members exercised less during lockdown compared to pre-lockdown, while non-gym members exercise duration did not change significantly from before to during lockdown. The closure of gyms disproportionately affected those with less home equipment, who reported a greater relative reduction in number of hours spent exercising than those with more home equipment. Access to home equipment, in other words, can mitigate the negative effects of gym closures on physical activity.

## Gym Member vs. Non-Gym Member

Compared to non-gym members, gym members increased their social media use more during lockdown (gym members: *M* = 67.06, *SD* = 19.17; non-gym members: *M* = 61.90, *SD* = 18.70; $t(410) = 2.70$, $p = .007$), felt more pressure from social media to exercise during lockdown (gym members: *M* = 41.45, *SD* = 28.05; non-gym members: *M* =29.50, *SD* = 26.24; $t(368) = 4.09$, $p < .001$), and also felt more pressure to transform their body during lockdown (gym members: *M* = 42.38, *SD* = 30.13; non-gym members: *M* =32.19, *SD* = 29.71; $t(368) = 3.23$, $p = .001$). Compared to non-gym members, gym members reported more anxiety not being able exercise as normal during lockdown (gym members: *M* = 48.04, *SD* = 29.93; non-gym members: *M* = 32.03, *SD* = 29.15; $t(424) = 5.49$, $p < .001$), gym members reported more frustration not being able exercise as normal during lockdown (gym members: *M* = 58.03, *SD* = 31.15; non-gym members: *M* =37.48, *SD* = 31.21; $t(424) = 6.70$, $p < .001$), gym members reported more being more depressed not being able exercise as normal during lockdown (gym members: *M* = 44.38, *SD* = 29.93; non-gym members: *M* =30.16, *SD* = 27.53; *t*(424) = 4.99, $p < .001$) (see Table 15).

Table 15 Means, standard deviations, and t-tests for social media influence and mood disturbance measures (current anxiety, frustration, and depression) due to not being able to exercise as normal between gym and non-gym members.

| | Gym Member (n = 240) | | Non-Gym Member (n = 172) | | |
|---|---|---|---|---|---|
| Measures | *M* (%) | *SD* | *M* (%) | *SD* | T-test results |
| Social Media | | | | | |
| Usage | 67.06 | 19.17 | 61.90 | 19.21 | *t* (410) = 2.70, *p* = .007 |
| Affect | 42.19 | 18.70 | 44.13 | 19.77 | *t* (410) = 1.01, *p* = .311 |
| Perceptions of Support | 53.05 | 21.28 | 51.64 | 19.66 | *t* (380) = 0.66, *p* = .511 |
| Exercise Pressure | 41.45 | 28.50 | 29.50 | 26.64 | *t* (368) = 4.09, *p* < .001 |
| Body Pressure | 42.38 | 30.13 | 32.19 | 29.71 | *t* (368) = 3.23, *p* = .001 |
| Mood | | | | | |
| Anxiety | 48.04 | 29.93 | 32.03 | 29.15 | *t* (424) = 5.49, *p* < .001 |
| Frustration | 58.03 | 31.15 | 37.48 | 31.21 | *t* (424) = 6.70, *p* < .001 |
| Depression | 44.38 | 29.93 | 30.16 | 27.53 | *t* (424) = 4.99, *p* < .001 |

# Discussion

This study aimed to determine how lockdown impacted exercise engagement in both those at-risk of MD and the UK exercise community, with a particular emphasis on gym members. We found that increased MD symptoms predicted increased mood disturbance due to not being able exercise as normal in those at-risk of MD (H1), and these effects were enhanced for those with less access to home gym equipment and who had reduced perceptions of support from social media. The self-reported increase in depression and frustration towards being unable to exercise as normal in gym members at-risk of MD, may be arguably due to them having to make significant adjustments for exercising at home due to the forced sudden inaccessibility of gyms and their dependence on gym equipment. Similar to prior studies on physical activity (Stockwell et al., 2021; Wilke et al., 2021), we found that the time spent exercising reduced; in our sample there was an overall 22.2% reduction in the number of weekly hours exercised, from 6 hours 49 mins before lockdown to 5 hours 18 minutes during lockdown (H2). Unlike previous studies, we also showed that the reduction in time spent exercising during lockdown was significantly greater in gym members than non-gym members, as well as in those with limited home equipment (≤ 1 piece of equipment) compared to exercisers with access to more home equipment (≥ 2 pieces of equipment) (H2+H3). The change in time spent exercising from pre to during lockdown predicted the severity of current anxiety, depression, and frustration due to not being able to exercise as normal, especially in gym members, excessive exercisers, and those with less home equipment. These findings are consistent with previous literature, which reported that a reduction in exercise during lockdown was associated with reduced wellbeing and an increase in negative mood (Kaur, Singh, Arya, & Mittal, 2020; Brooks et al., 2020; Ingram, Maciejewski, & Hand, 2020; Maugeri et al., 2020). Our findings also support our hypothesis (H4) that more frequent use of social media during lockdown would be associated with greater exercise-related mood disturbance.

Altogether, these results represent the first direct demonstration that UK gym members at-risk of MD experienced greater anxiety, depression, and frustration from the government-induced restrictions of exercise engagement during the COVID-19 pandemic. Furthermore, we found that the wider gym population were disproportionately affected by government-induced restrictions of exercise engagement during the COVID-19 pandemic compared to those who exercised without a gym membership pre-lockdown.

**The association between gym members at-risk of muscle dysmorphia, change in exercise, home gym equipment access, and social media engagement on mood.**

Our findings support our hypothesis that increased MD symptoms in gym members at-risk of MD and an increase exercise change, reduced quantity of home gym equipment and increased social media engagement in gym members at-risk of MD was be associated with increased current mood disturbance. These findings indicate that gym members at-risk of MD mood state was negatively impacted from being unable to access as much gym equipment as they usually would during the lockdown. Previous research has highlighted those at-risk of MD are dependent on use of gym equipment for their regular exercise routine (Olivardia, 2001; Olivardia, Pope Jr, & Hudson, 2000; Pope Jr, Gruber, Choi, Olivardia, & Phillips, 1997).

In accordance with previous literature which has demonstrated an association between social use and body shaming (Fatt, Fardouly, & Rapee, 2019; Hanna et al., 2017; Wang et al., 2019), these current findings arguably indicate that gym members at-risk of MD may be at greater risk for developing heightened negative mood, including depression. Therefore, despite gym closures being necessary to contain virus transmission, these closures may have contributed significantly towards a decrease in mental health and body image related corcerns in gym members at-risk of MD, in addition to the overall increase in mental health conditions observed during the lockdown (Daly, Sutin, & Robinson, 2022).

**The effect of lockdown on exercise reduction and exercise-related mood**

This study hypothesised that a decrease in exercise engagement from before to during lockdown would be associated with increased mood disturbance, and that mood disturbance would be more pronounced for gym members compared to non-gym members. As hypothesised, the decline in average number of hours spent exercising per week was far greater for gym members (38.1% decline) than non-gym members (a non-significant 2.5% decline). These finding support previous studies focusing on active individuals during COVID-19 pandemic-related lockdowns, which also found pronounced exercise reductions in active individuals when compared to less active individuals (Hargreaves et al., 2021; Fearnbach et al., 2021; Castañeda-Babarro, Arbillaga-Etxarri, Gutiérrez-Santamaría, & Coca, 2020; Giustino et al., 2020). These findings may be explained through non-gym members already having an established exercise routine (either at home or in freely accessible outdoor spaces), whereas gym members may have had to make significant adjustments for exercising at home due to the forced sudden inaccessibility of gyms. In addition, non-gym members may have favoured different types of exercises (e.g., aerobic exercises like running), while gym members may have depended on gym-based apparatus (e.g., smith machine) and equipment (e.g., barbell).

We found that gym membership (without being able to access gyms) predicted greater depression and more frustration towards being unable to exercise as normal. These findings support previous studies demonstrating that mood deteriorates when exercise regimes are either interrupted (Peluso & De Andrade, 2005; Wittig, McConell, Costill, & Schurr, 1992; Mondin et al., 1996; Szabo et al., 1998), or completely withdrawn (Berlin, Kop, & Deuster, 2006). Therefore, despite gym closures being necessary to reduce virus transmission, such closures may have contributed significantly towards the observed increase in mental health conditions during the lockdown.

## Access to home gym equipment mitigates reductions in exercise and mood

Another hypothesis of this study was that limited access to home gym equipment would be associated with greater reductions in exercise and increased mood disturbance. In support of this hypothesis, we found that the reduction in exercise was greater in those with ≤ 1 piece of home equipment (31.7% decline) compared to those with ≥ 2 pieces of home equipment (14.4% decline). This would suggest that having access to home exercise equipment is crucial for continuing engagement in exercise at home. Previous research focusing on home-based exercise interventions has also indicated that access to home equipment is a contributing factor towards exercise adherence in general (Taylor, Dodd, McBurney, & Graham, 2004; Jakicic, Winters, Lang, & Wing, 1999). Although the importance of access to home equipment in mitigating exercise decline was only seen in gym members, there was no overarching interaction between gym membership, home equipment and change in exercise, however, suggesting that this finding should be interpreted with some caution.

We further hypothesised that limited pieces of home gym equipment would be associated with increased mood disturbance. It was found that fewer pieces of home gym equipment were associated with increased exercise-related anxiety and depression. These findings highlight the importance of possessing suitable exercise home-equipment to enable exercising as preferred or with reasonable adjustments when in lockdown, as it could be contributing to self-perceptions of anxiety and depression related to not being able to exercise as normal.

**The effect of social media use on exercisers' mood**

Our findings also support our hypothesis that more frequent use of social media during lockdown would be associated with greater exercise-related mood disturbance. It was found that increased social media use related to increased perceptions of anxiety and frustration towards not being able to exercise as normal. Furthermore, increased perceptions of negative affect from using social media related to increased perceptions of anxiety, frustration, and depression towards an inability to exercise as normal. Additionally, increased perceptions of both social media pressure to exercise and social media pressure to 'transform' their body during the lockdown, related to increased perceptions of anxiety, frustration, and depression towards not being able to exercise as normal.

When comparing the effect of social media between gym members and non-gym members, it was found that gym members reported significantly greater social media usage, social media pressure to exercise and to 'transform' their body during the lockdown compared to non-gym members. There were no differences found in perceptions of social media support and perceptions of affect from social use during the lockdown between gym members and non-gym members. These findings imply that during the lockdown gym members were not only using social media more, but also perceiving greater pressure to exercise and 'transform' their body compared to non-gym members. These findings therefore support previous studies which found gym members to be at greater risk for developing issues related to body image and mental health concerns in comparison to non-gym members (Prichard & Tiggemann, 2008; Stapleton, McIntyre, & Bannatyne, 2016). In contrast to previous literature, there were non-significant effects of both age and gender across all social media measures (Correa, Hinsley, & De Zuniga, 2010).

Taken together, findings are consistent with previous literature that found social media usage negatively impacts on both mental health (Frith, 2017; Shaw, Mitchell, Welch, & Williamson, 2015) and body image amongst the general population and exercisers (Fardouly & Vartanian, 2016; Griffiths, Murray, Krug, & McLean, 2018; Gültzow, Guidry, Schneider, & Hoving, 2020; Saiphoo & Vahedi, 2019; Tiggemann, & Zaccardo, 2015). Therefore, increased social media pressure to engage in exercise, in general, and for appearance related reasons during the lockdown, has arguably led to an overall increase in appearance-related motivations for exercising. This appearance-related emphasis for exercising is likely to have led to a greater susceptibility of disordered eating (Furnham, Badmin, & Sneade, 2002), increased body dissatisfaction (LePage & Crowther, 2010), and MD symptomatology (Olivardia, 2001) in exercisers' during the lockdown.

**Limitations**

Several limitations are noted. First, measurement for exercise change was only considered in terms of duration, and not in activity and/or intensity. Second, this study did not consider the function or size of the home equipment and the extent to which it could support exercisers' regular exercise routines. For instance, research has demonstrated that large home exercise equipment (e.g., treadmills) are more effective than smaller exercise equipment (e.g., resistance bands) in facilitating physical activity in adults (Kaushal & Rhodes, 2014). A final limitation of this study is that it only considered social media use in general, rather than ask specific questions on the type of social media platform/s and content our sample engaged in. Previous research has shown that social media platforms with a high proportion of image-centric content (e.g., Instagram) are associated with muscularity dissatisfaction and eating disorder symptoms, when compared with less image-centric social media platforms (Griffiths, Murray, Krug, & McLean, 2018).

## Conclusions

Despite these limitations, the present study has enhanced our understanding of the impact of gym closures during the COVID-19 pandemic on the gym members at-risk of MD and the wider UK exercise community. The present study has demonstrated that gym members at-risk of MD experienced enhanced mood disturbance during the lockdown, these effects were enhanced for those with less access to compensatory home gym equipment and reduced perceptions of support from social media. The present study has also demonstrated that gym members have experienced disproportionate levels of mood disturbance, reduced exercise engagement, and perceived social pressures to exercise for appearance-related reasons particularly in comparison to non-gym members. These effects were elevated in those with less access to compensatory home gym equipment, and in those with a greater propensity to exercise excessively. This study has implications for understanding how to support gym members at-risk of MD and (and the wider exercising community) should future lockdowns be imposed, in a similar pandemic situation and/or during the return to living with limited restrictions on accessing shared facilities for physical exercise.

# Chapter 5 The Visuospatial Body Map task: Development and validation of a new approach to measuring explicit representations of body structure

## Abstract

Representations of our bodies can determine how our bodies feel to us, how we experience them. The present study aimed to investigate the possibility that distorted body-configural representations measured by an online visuospatial body map task may be an indicator of body image concern amongst a sample from the general population (*n* = 706 respondents, 214 males, 487 females, 5 other). We found that improved visuospatial body map choice task performance was associated with increased body image disturbance in females. Secondly, we found that body part estimation accuracy did not relate to measures of body image disturbance in our sample. This study has implications for understanding the extent to which measures of visual body representation can be used to assess body image concerns in the general population. This study also demonstrates the importance of developing body representation protocols that are specific to each body image disorder.

# Introduction

Cognitive neuroscientific research has demonstrated that perception does not result from a simple flow of sensory information from periphery to cortex ("bottom-up" processing). Rather, cortical and limbic regions play a role in selecting information most likely to be relevant considering an individual's experience and expectations ("top-down" processing) (Epstein et al., 2001). This understanding raises the possibility that data cited to support the existence of body size distortion in eating disorders may reflect top-down processing related to attitudinal disturbances, rather than abnormalities in more basic, bottom-up perceptual functions (Smeets, 1997). That possibility is consistent with recent studies employing measures of biases in attention, memory, judgment, and response which suggest that body size distortion in eating disorders may result from cognitive bias (Williamson, 1996; Smeets, Ingleby, Hoek, & Panhuysen, 1999; Gardner, & Bokenkamp, 1996). In the context of body image, we constantly receive top-down (i.e., prior knowledge, memory, expectation about those aspects of our body) and bottom-up (info from sensory organs that can inform us about our body's shape, weight, and size) information that builds up a mental representation of our own bodies. Research has attempted to understand the underlying cognitive mechanism of this mental representation in terms of body representation and body image (Brooks, et al 2020; Caggiano, & Cocchini, 2020; Fuentes, Longo & Haggard, 2013). Body representation is referred as to sensorimotor representations based on afferent and efferent information (Brooks, et al 2020; Cornelissen et al, 2019), which allows us to move through our environment. Within body representation literature, a distinction exists between two kinds of information: short-term and long-term. Short-term information is delivered by afferent receptors: joint position, tendon tension and the like. In contrast, long-term information refers to the spatial characteristics of the body (i.e., size and shape), which aren't directly and consistently available via afferent signals (de Vignemont, 2014; Pitron, & de Vignemont, 2017). The long-term spatial body representation, in addition to representing body parts within the context of the body, is also multimodal in that it receives visual and proprioceptive inputs. Further it represents not only our own body but also the bodies of other people (Reed & Farah, 1995; Reed, & McIntosh, 2008). Body image, however, is based on perceptually processing the sizes and shapes of body parts and their arrangements to form a whole (Caggiano, & Cocchini, 2020), which allows us to have cognitions and emotions about our own and others' bodies. Body image can be thought of as a multidimensional construct that embraces a person's conscious perception of their physical self, including the thoughts and feelings that result from that perception. One's body image is developed and maintained via complex interactions between socio-cultural, neurophysiological, and cognitive factors: it is central to our self-concept and influences our psychology and behaviour (Stice & Shaw, 2002).

Disturbed body image can lead to dramatic attempts by the individual to alter their appearance. Patients with EDs such as AN, for example, may engage in self-starvation (Stice & Shaw, 2002) will and often insist that they are fat, even while completely emaciated (Treasure, Claudino, & Zucker, 2010). Such body image distortions are strong predictors of negative prognosis (Casper, Halmi, Goldberg, Eckert, & Davis, 1979) and of relapse following recovery (Keel, Dorer, Franko, Jackson, & Herzog, 2005). Other body image related disorders such as BDD, which is characterised by a preoccupation with imagined or slight physical defects in appearance (e.g., shape or size of nose) (Phillips, Didie, Feusner, & Wilhelm, 2008). Individuals with BDD often think about their perceived defect for many hours per day, and they frequently engage in time-consuming repetitive behaviours such as comparing, mirror-checking, camouflaging, excessive grooming, or reassurance-seeking (Phillips, McElroy, Keck, Pope, & Hudson, 1993). MD is a subtype of BDD (DSM-5, 2013), typical behaviours associated with MD include engagement in excessive gym attendance, strict diet regimes to increase muscle mass, and appearance enhancing substance use (Olivardia, 2001; Pope, et al., 1997). MD's defining feature is the belief that one's body is small, insufficiently muscular and or lean, despite one's body being objectively muscular in size (Grieve, 2007; DSM-5, 2013; Pope et al., 2000).

Body image disturbance is not only a symptom of body image and related disorders, but it also plays a causal role in the development, persistence, and relapse of such disorders. However, there is still much unknown about the processes that underlie the onset and maintenance of body image and related disorders (for review, see Glashouwer et al., 2019). Some researchers consider body image disturbance more as a symptom than a driving force of body image and related disorders. However, others emphasise body image disturbance as a causal factor in the development, persistence, and relapse of EDs and consider body image disturbance therefore as an important target in the treatment of body image related disorders.

Body representations can be defined (minimally) as internal cognitive structures that "function to track the state of the body and encode it, that can misrepresent it and that can be decoupled from it" (de Vignemont, 2016). Body representations are fundamental to many of our cognitive abilities. To be able perform different cognitive tasks, our brains must represent features of our bodies and their structural relations. In order to mentally picture what our body looks like, we rely on a representation of it in the form of a mental image. Representations of our bodies can determine how our bodies *feel* to us, how we *experience* them. Because of this, disorders in the way people experience their bodies allow us to better understand how the brain represents the body (Schilder, 1935). For example, in phantom limb disorder patients still feel the presence of a limb that has been amputated (Flor, 2002; for a review see Collins et al., 2018), and with body integrity identity disorder, a limb is said to be *missing* from a patient's body representation (Brang, McGeoch, & Ramachandran, 2008; Brugger, Kurthen, Rashidi-Ranjbar, & Lenggenhager, 2018; for a review see Sedda & Bottini, 2014). This causes the patient to have an extreme desire to amputate the limb. There is ample evidence to suggest that individuals with EDs are not able to optimally integrate incoming visual and proprioceptive/tactile/kinaesthetic information to update a current 'online' body percept (e.g., Keizer et al., 2011; Zucker et al., 2013) and may therefore be relying upon a stored and distorted body representation. Indeed, functional imaging studies in participants with and recovered from AN have supported this. Where both the AN group and the recovered AN group have displayed decreased connectivity in areas of the ventral visual network, a network involved in the "what?" pathway of visual perception. Furthermore, the AN group, but not the recovered AN group, displayed increased coactivation in the left parietal cortex, encompassing the somatosensory cortex, in an area implicated in long-term multimodal spatial memory and representation (Favaro et al., 2012). A neuropsychological assessment of visuospatial abilities revealed that aspects of detail processing and global integration (central coherence) showed correlations with connectivity of this brain area in the AN group (Favaro et al., 2012).

It has been known for some time that AN patients also have a persistent disturbed experience of their own bodies, specifically their body's *size* or *shape* (DSM-5, 2013). Many report that this experience arises as a result of distorted body representations (Gadsby, 2017, Keizer, Smeets, Postma, van Elburg, & Dijkerman, 2014; Keizer et al., 2013; Spitoni et al., 2015).

To measure explicit representations of body structure, the Body Schema Task, (a.k.a Daurat-Hmeljiak Test) (Daurat-Hmeljiak et al., 1978) was developed to provide information about the spatial organisation of the body and whilst allowing quantitative study the body image without explicitly asking about body size and shape (Fuentes, Longo, & Haggard, 2013; Cimmino et al., 2013; Palermo, Di Vita, Piccardi, Traballesi, & Guariglia, 2014). The Body Schema Task involves placing one tile depicting a body part in the appropriate position on an empty board, where the contour of the model's face was drawn, in order to reconstruct the model's entire body as accurately as possible. After each trial, the previously placed tile was removed, and the board was returned completely empty. Therefore, participants had to refer to an internal representation of a human body image that depend on the representation of their own physical body to perform the task (Di Russo et al., 2006). The Body Schema Task had a total of 9 tiles (right arm, left arm, right leg, left leg, right hand, left hand, right trunk, left trunk, neck).

Since, Fuentes, Longo, and Haggard (2013) have adapted the Body Schema Task, where participants from the general population were asked to judge the location of a body part relative to the head (an anchor), achieved via both an in-person and an online adapted Body Schema Task on a computer screen. Results showed an over-estimation of the width in the shoulder area and the length of the upper arms in comparison to the height. Also, there was an underestimation of the lengths of the lower arms and legs. More recently, the Body Schema Task has been modified to be more representative of a life-sized body, achieved by illuminating an area on a wall (approximately $140 \times 192$ cm in size and 150 cm from the floor), where participants from the general population used a laser pointer to indicate where they thought the body parts would be (Caggiano, Bertone, & Cocchini, 2021). They found that participants showed a tendency to underestimate the length of most of their body parts, in particular the lower arms (− 44%) and overestimate the torso (+ 10%) and lower legs (+ 7%).

Understanding body image distortion in the way one perceives the shape and size of bodies is a key component of diagnosing and developing treatments for eating disorders and BDD, of which MD is a subtype (DSM-5, 2013; Fuentes, Longo, & Haggard, 2013; Grieve 2007; Olivardia, 2007). Spitoni et al., (2015) used the Body Schema Task to measure explicit representations of body structure in a sample of female AN patients and healthy female controls. They found that AN patients showed an impaired ability to position the tiles depicted body parts in an empty board compared to healthy controls. Interestingly the shape of the mannequin made by AN was wider but not longer than that of controls, suggesting that AN patients represent their body wider but not wholly bigger.

The present study aimed to investigate the possibility that distorted body-configural representations (as measured by the visuospatial body map task) may be an indicator of body image concerns (as measured by survey responses) in a more systematic way. First, we aimed to measure the relationship between configural processing and body image in both women and men across the wider population (including healthy persons and persons with subclinical symptoms of body image disturbance). Second, we aim to extend Spitoni et al.'s (2015) study using line drawings of a genderless body by including adult gendered bodies (female vs. male bodies) and a variety of body shapes (lean, muscular, or hyper-muscular) to test the potential specificity of this relationship for configural (vs. feature-based) processing of bodies of one's own (vs. another) gender. Third, we used an online version of the tasks to assess their suitability for rapid identification of persons at risk of body image disturbances.

For the visuospatial body map task participants were presented with an image of a body on a computer screen. Participants were required to memorise the body. After, participants were presented with three body part probes, which were all the same body part but different in muscularity (one was the original body part, and the other two were more and less muscular than the original body part). Participants were tasked with selecting the body part which corresponded to the body part presented in the original image. Once the choice was made, participants were required to drag the chosen body part and drop it where they estimated the body part was presented previously when it was part of the full body. Once participants had estimated the location of the body part another body part was presented for the choice task until all the body parts were estimated (i.e., left arm, abdomen, chest, right arm, right leg, left leg).

We hypothesised as follows:

H1: Increased levels of body image concern (ED, BDD, MD) would predict increased task performance (measured by both correct selection and location estimation of body parts) on the visuospatial body map task.

H2: Increased levels of body image concern (ED, BDD, MD) would predict over-estimation of body width on the visuospatial body map task.

H3: Body image concern (ED, BDD, MD) would not predict estimation accuracy of body length on the visuospatial body map task.

# Experiment 1

The purpose of Experiment 1 was to determine a maximum time required to memorise the initial full body presentation. The full body presentation in Experiment 1 was self-paced, which enabled researchers to establish both the mean time required to memorise the full body and provide justification for a fixed full body presentation time period to memorise the body in Experiment 2. Also, Experiment 1 was an opportunity to pilot this novel online task and to ensure participants were able to complete the task as intended.

# Material and methods

## Participants

58 participants were recruited using the Prolific Platform (https://www.prolific.ac/). Written (digital) informed consent was obtained from all participants prior to participation.

## Ethical Declaration

The study was approved by the local Ethics Committee for the Psychology Department at the University of Essex (Ethics ID: ETH1920-1045).

## Visual Stimuli

The images of the bodies were all from the front view, and heads were fully covered with a black silhouette during the task (see Fig 31.). The bodies were rendered through DAZ Studio 4.12 (www.Daz3d.com), using the male and female Genesis 8 model. Each stimulus differed on "bodybuilder" details with scaling of 40, 70 and 100 (achieved using the built-in Daz Studio 4.12 scaling in the following features (Fig 31.).

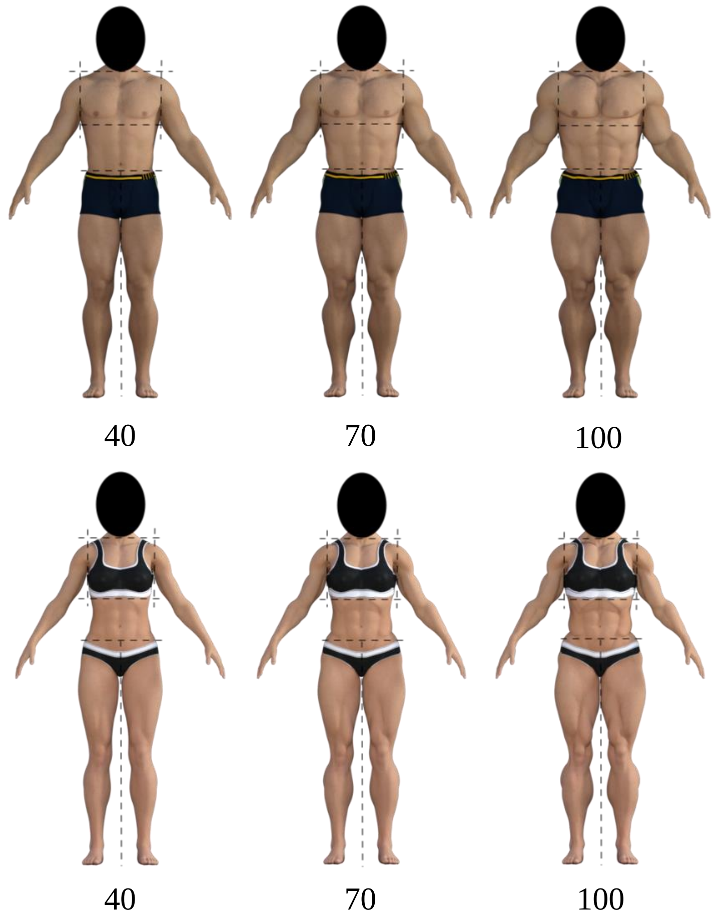



Figure 32. Example male and female stimuli for the visuospatial body map task (with Bodybuilder details scaled at 40 (lean), 70 (muscular), and 100 (hyper-muscular)). Dotted lines indicate the body part sections each body will be split up into. The size of the figure was controlled for regardless of screen size, measuring 450px height x 550px width.

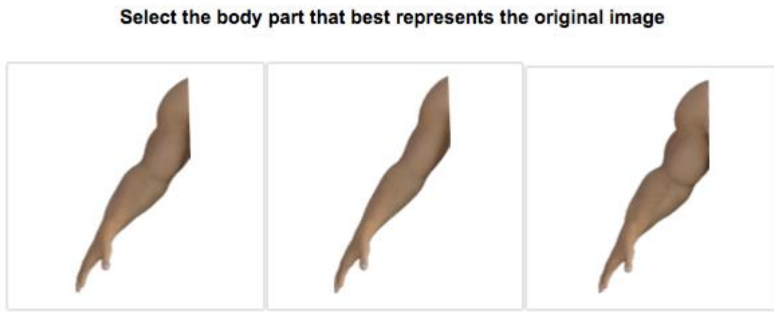



Figure 33. Example body part stimuli (male left arm) with the bodybuilder details scaled at 40 (centre), 70 (left), and 100 (right). The order of the body part stimuli was randomised.

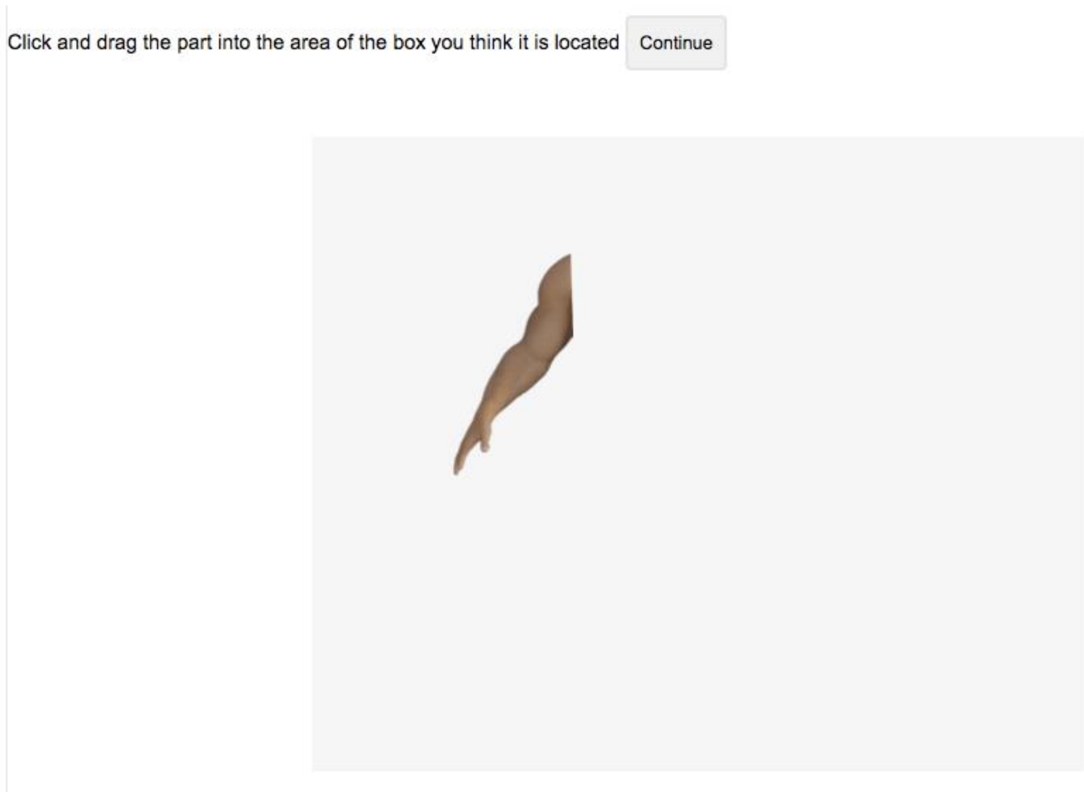



Figure 34. Example area of the screen for body part location estimation, the size of the area was controlled regardless of screen size, measuring 450px height x 550px width.

## Procedure

We designed and conducted the experiment online using the lab.js platform (https://lab.js.org/). Firstly, written (digital) informed consent was obtained from all participants prior to participation. Consenting participants continued to the survey and then the embedded visuospatial body map task. Participants were instructed to set their computer to 'full screen mode' to facilitate the visuospatial body map task.

The experimental phases (see Figure 35) consisted of the following sequence: Firstly, a fixation dot was display for 500 ms, followed by the full body presentation which could be either a female or male body. Participants were required to memorise the full body presentation, which was self-paced. After, participants were presented with three body parts, which were all the same body part but different in muscularity (one was the original body part, and the other two were more and less muscular than the original body part). Participants were tasked with selecting the body part which corresponded to the body part presented in original full body, which was self-paced. This was followed by the mask phase for 500 ms. Following this, the participants chosen body part was presented, and the participants tasked with dragging the body part and dropping it where they estimated the body part was presented during the full body presentation phase. This was then repeated for all the other body parts. Once all the body parts were presented, which occurred in a fixed order (left arm, chest, abdomen, right arm, right leg, left leg) another body was presented. There were six different full body presentations: three female bodies (with 3 different levels of muscularity) and three male body bodies (with 3 different levels of muscularity), resulting in a total of 216 body part location estimations per participant. All bodies were presented in random order to control for any practice and/or fatigue effects. Participants were instructed to complete the task as accurately and as quickly as possible.

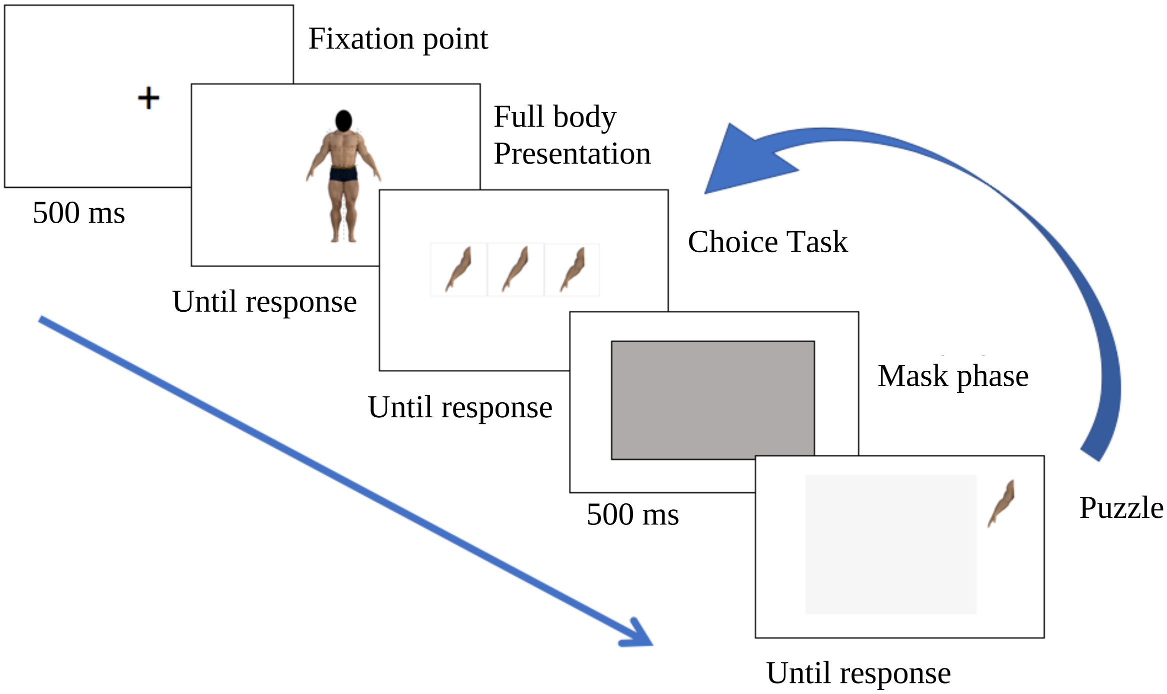



Figure 35. Schematic representation of the stimuli and procedure.

## Data Analysis

For data analysis and processing we used R (R core team, 2017). We examined: (1) the effect of memorising the dimension of a body on a choice-task paradigm, and (2) the effect of spatial location on the visuospatial body map task paradigm. There were two independent variables in the body presentation: (a) female body, and (b) male body. Our dependent variables were: (1) accuracy from the choice-task paradigm, (2) estimation accuracy on the x axis from the visuospatial body map task, (3) estimation accuracy on the y axis from the visuospatial body map task, (4) response times from choice-task paradigm, (5) response time for estimation of body part locations.

# Results

## Body part choice task performance

### Descriptive Statistics for the choice-task paradigm

From the 58 participants, 12 participants were discarded because of incomplete data and/or because responses were too fast to be realistic. This left 46 participants (28 males; 18 females) and a total 432 trials for the lean condition, 322 for the muscular condition, and 437 for the hyper-muscular condition. All participants responded under 20,000 ms after the onset of the full body presentation (time taken to memorise the body) (*M* = 11,564.29, *SD* = 3,875.99).

Mean accuracy separated by body part is presented in Table 16. On average, participants' accuracy in the choice task was 81.70% (*SD* = 38.7) in the lean condition, 55.90% (*SD* = 49.7) in the muscular condition, and 86.50% (*SD* = 34.2) in the hyper-muscular condition (Table 17). Accuracy was higher for male than female hyper-muscular (95.3% vs 74.6%) and lean bodies (85.7% vs 75.7%), and accuracy was higher for female than male muscular bodies (59.2% vs. 49.4%).

Table 16 Mean accuracy (%) on the choice task as a function of body parts.

| Body Part | Trials | Accuracy (%) | |
|---|---|---|---|
| | | *M* | *SD* |
| Abdomen | 198 | 77.3 | 42.0 |
| Chest | 207 | 74.9 | 43.5 |
| Left arm | 163 | 78.5 | 41.2 |
| Left leg | 219 | 73.1 | 44.5 |
| Right arm | 225 | 75.1 | 43.3 |
| Right leg | 179 | 81.6 | 38.9 |

Table 17 Mean accuracy (%) separated for each body size (level of muscularity) and gender.

| Condition | Lean | | Muscular | | Hyper-muscular | |
|---|---|---|---|---|---|---|
| Body Presentation | Male | Female | Male | Female | Male | Female |
| *M* | 85.7 | 75.7 | 49.4 | 59.2 | 95.3 | 74.6 |
| *SD* | 24.7 | 32.1 | 37.1 | 37.5 | 12.7 | 33.0 |

## Response time for the choice-task paradigm

Only correct body part choice responses were analysed in this section. We discarded the muscular condition from this analysis, due to poor accuracy on the task. Sample mean response times and standard deviations (presented in Table 18) were subject to a within-subject analyses of variance (ANOVA) with the factors of body dimension (lean, hyper-muscular) and body image presentation (male, female). There was a significant main effect for body size ($F$ (1, 36) = 18.089, $p$ < 0.001 $\eta^2$ = .334), indicating that participants were faster when responding to lean bodies. There was no main effect for body gender ($F$ (1, 36) = 1.871, $p$ = .180 $\eta^2$ = .049). However, there was a significant effect in the interaction between body size and body gender ($F$

(1, 36) = 16.533, $p < 0.001$ $\eta^2 = .315$). Follow-up, pairwise comparisons revealed that body size effects (faster responses to lean than hyper-muscular bodies) were significant for female ($t$ (36) = 2.720, $p < 0.001$), but not for male ($t$ (36) = 0.614, $p = 0.534$) bodies, indicating that responses to male and female bodies did not differ from one another for lean bodies, but responses to male bodies were significantly faster than those to female bodies when choosing hyper muscular bodies

Table 18 Mean correct response times (in milliseconds) on the choice task as a function of body size and gender.

| Condition | Lean | | Hyper-muscular | |
|---|---|---|---|---|
| Body Presentation | Male | Female | Male | Female |
| *M* | 2099.9 | 2161.2 | 2025.9 | 2570.9 |
| *SD* | 580.7 | 795.6 | 558.6 | 645.2 |

In summary, our findings from Experiment 1 suggest that 20,000 ms will be a suitable fixed timeframe for memorising the initial full body presentation in Experiment 2. Also, our findings in relation to correct responses suggest that the online visuospatial body map task has suitable levels of difficulty which enable distinguishment of inferior and superior task performance. We can conclude that Experiment 1 demonstrates that the visuospatial body map task has potential to be a suitable online measure of body representation amongst the general population.

# Experiment 2

Experiment 2 was designed to replicate and build on the results of Experiment 1 by employing a similar paradigm. However, in this study we introduced two relevant changes aimed at making the task more difficult – one was by controlling the length of time the stimuli were displayed. We also incorporated psychometric measures related to body dissatisfaction. The purpose of Experiment 2 was to establish the relationship between performance on the visuospatial body map task and psychometric measures of body image concern.

# Material and methods

## Participants

Adults (18- 65 years) living in the UK were recruited online using advertisements shared on social media by the research team. Using G*Power for an a priori power analysis, for a within-subject analyses of variance (ANOVA), a Cohen (1988) *f* of 0.1 (i.e., a small effect size), and a power estimate of 80%, the recommended sample size is a minimum of 782 participants. A total of 784 unique respondents entered the survey. Of the 784 respondents, we only used data from those who answered the complete set of questions and the visuospatial body map task. 78 participants were removed due to an average response accuracy below chance (33.33%), in accordance with the predetermined exclusion criteria (https://aspredicted.org/3MB_227). This gave a total of 706 respondents, consisting of 214 males, 487 females, and 5 other. The age distribution of the participants ranged from 18 to 64 years (males $M$ = 31.22; $SD$ = 11.29; females: $M$ = 29.70; $SD$ =11.71; other $M$ = 28.80; $SD$ = 9.15). The study received ethical approval from the Department of Psychology, University of Essex. Prior to participation, participants provided electronic informed consent.

## Measures

All participants completed the following psychometric measures:

**Body Image Concern Inventory** (BICI, Littleton et al., 2005) was used to measure dysmorphic concerns (see Chapter 2 of this thesis for full details). In the present study, the Cronbach's α was .95, demonstrating strong internal consistency.

**Muscle Dysmorphic Disorder Inventory** (MDDI, Hildebrandt et al., 2004) was used to measure MD symptomology (see Chapter 2 of this thesis for full details). In the present study, the Cronbach's α was .78 for the MDDI total, demonstrating good internal consistency.

**Eating Disorder Inventory - Third Edition body dissatisfaction subscale** (EDI-3-BD, Garner, 2004) was used to measure body image dissatisfaction (see Chapter 2 of this thesis for full scale details). Each subscale has adequate psychometric properties to be used as separate construct scales (Garner, 2004). The EDI-3-BD subscale comprises 10 items, for example, "I feel my stomach is too big" and the response scale for each item has five ordered categories ranging from 0 (never) to 4 (always). In the present study, the Cronbach's α for this subscale was .89, demonstrating strong internal consistency.

## Procedure

Responding to the advertisement redirected potential participants to an information and consent page for the online study. Participants completed an online survey and embedded Visuospatial Body Map task supported by Qualtrics (https://www.qualtrics.com), which included general demographic information (e.g., age, sex, nationality) and psychometrics measuring body dissatisfaction. Consenting participants continued to the survey and then the embedded

Visuospatial Body Map task. Participants were instructed to set their computer to 'full screen mode' to facilitate the Visuospatial Body Map Task. The experimental phases consisted of the same sequence as Experiment 1 (see Figure 34.), except for the full body presentation which was limited to 20,000 ms for Experiment 2 (Experiment 1 was self-paced).

## Data analysis

Data preparation and analyses were planned and conducted using both R (R core team, 2017) and the IBM SPSS Statistics version 25. Descriptive statistics, inferential statistics (ANOVAs) and correlation tests were performed to understand the sample structure and study variables, and to test whether performance on the body map task systematically related to measures of body image disturbance. Similar to previous research, this analysis included estimation discrepancy as a measure of accuracy (Caggiano & Cocchini, 2020; Daurat-Hmeljiak et al., 1978). Four measures of accuracy were considered, firstly, one for average correct responses during the choice task, which was split by gender of the stimuli (male body & female body). Secondly, body part location estimation accuracy was considered, which was measured through distance (in pixels) on both the x axis and y axis, away from the mid-point on each original body part location. These distances were then averaged across trials for each body part and body presentation to get an average total body part estimation error for each axis. Third, average estimated body width was measured by calculating the average estimation pixel distance between the left arm (x axis) and the right arm (x axis) as well as between left leg and right leg. Finally, average estimated body length was measured by calculating the average estimation pixel distance between the chest (y axis) and legs (y axis). In order to investigate the links between body-structural processing and attitudes towards one's own body (dysmorphic concern and eating behaviours), Pearson's / Spearman's *r* correlational analyses were planned between task performance and questionnaire scores. Unlike Experiment 1 and given the larger number of participants, we also considered participant gender as an additional variable of interest in Experiment 2. The false discovery rate method of correction for multiple comparisons (Benjamini & Hochberg, 1995) was applied to correlation results, results that did not survive correction are not reported.

# Results

We analysed data from 706 participants aged 18 to 64 (male 30.3 %, female 69.0 %, other 0.7 %.). Scores on the BICI varied from 21 to 95 and the mean score was 54.28 (*SD* = 15.74), with 99 participants scoring above the cut-off score (>72) for clinical concern (Littleton et al., 2005). Scores on the EDI-3 body dissatisfaction subscale varied from 0 to 40 and the mean score was 17.47 (*SD* = 9.79). Scores on the MDDI varied from 13 to 56 and the mean score was 26.98 (*SD* = 7.80), with 52 participants scoring above the proposed cut-off for high MD symptoms (>39) (Varangis et al., 2012). Forty-six trials were excluded as the response times on the choice task were below 150 ms.

## Choice task accuracy

Mean accuracy separated by body part is presented in Table 8. Table 11 represents the mean accuracy on the choice task. As in Experiment 1, accuracy for male bodies was higher than accuracy for female bodies. On average, participants' accuracy was higher for male than female lean bodies (68.44% vs 49.72%), muscular bodies (43.08% vs. 39.75%), and hyper-muscular bodies (80.69% vs 67.75%) (Table 19). Mean response accuracies were subject to a within-subject analyses of variance (ANOVA) with the factors of body dimension (lean, muscular, hyper-muscular) and body gender (male, female). There was a significant main effect for body dimension ($F$ (2, 1410) = 472.26, $p < 0.001$ $\eta^2 = .401$). There was a main effect for body gender ($F$ (1, 705) = 100.35, $p < .001$ $\eta^2 = .125$). Also, there was a significant effect in the interaction between body dimension and body gender ($F$ (2,1410) = 40.51, $p < 0.001$ $\eta^2 = .054$). Pairwise comparisons of estimated marginal means at each level of body dimension and body gender showed that correct responses differed across groups and conditions (see Figure 36). Accuracy was higher for male than female lean and muscular bodies, but similarly accurate for hyper-muscular bodies. Accuracy in each body dimension differed from each other body dimension (Figure 36).

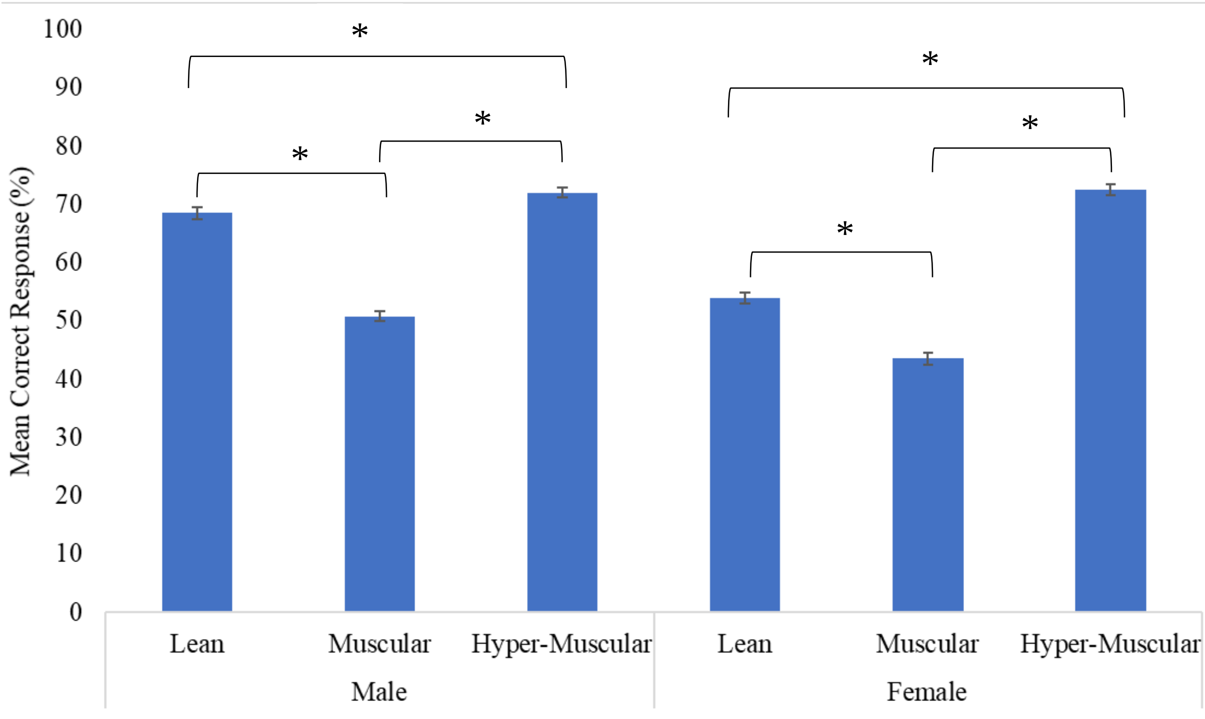



Figure 36. Mean correct responses (%) on the choice task. Error bars depict standard error of the means, and asterisks indicate significant pairwise comparisons (p <.05).

Table 19 Mean correct responses (%) separated for each body dimension and body gender.

| Condition | Lean | | Muscular | | Hyper-Muscular | |
|---|---|---|---|---|---|---|
| Body Presentation | Male | Female | Male | Female | Male | Female |
| *M* | 68.46 | 53.94 | 50.80 | 43.50 | 72.00 | 72.52 |
| *SD* | 25.66 | 24.53 | 22.60 | 28.06 | 20.72 | 24.89 |

## Choice task response times

Only correct body part choice responses were analysed in this section. Response times mirrored accuracy data to some extent: both male and female participants were faster to respond to male than female bodies except for the muscular condition (Table 12). Sample mean response times and standard deviations (presented in Table 20) were subject to a within-subject analyses of variance (ANOVA) with the factors of body dimension (lean, muscular, hyper-muscular) and body gender (male, female). There was a significant main effect for body dimension ($F$ (2, 1084) = 24.39, $p$ < 0.001 $\eta^2$ = .043), indicating that participants were fastest when responding to lean bodies. There was a main effect for body gender ($F$ (1, 542) = 4.53, $p$ = .034 $\eta^2$ = .008), indicating that participants were faster when responding to male bodies. Also, there was a significant effect in the interaction between body dimension and body gender ($F$ (2, 1084) = 26.98, $p$ < 0.001 $\eta^2$ = .047). Pairwise comparisons of estimated marginal means at each level of body dimension and body gender showed that correct RTs differed across groups and conditions (see Figure 37). RTs were quicker for male than female body stimuli in lean and hyper-muscular body dimensions, but the opposite was the case for the muscular body dimension. The largest difference between male and female bodies was seen for the hyper-muscular condition, where male body parts were correctly selected much more quickly than female body parts.

Table 20 Mean correct response times (in milliseconds) on the choice task as a function of body dimension and body gender.

| Condition | Lean | | Muscular | | Hyper-muscular | |
|---|---|---|---|---|---|---|
| Body Presentation | Male | Female | Male | Female | Male | Female |
| *M* | 2531.0 | 2911.9 | 3890.9 | 3330.0 | 2237.59 | 3906.8 |
| *SD* | 3389.2 | 2777.5 | 2836.2 | 3999.4 | 2662.0 | 3530.35 |

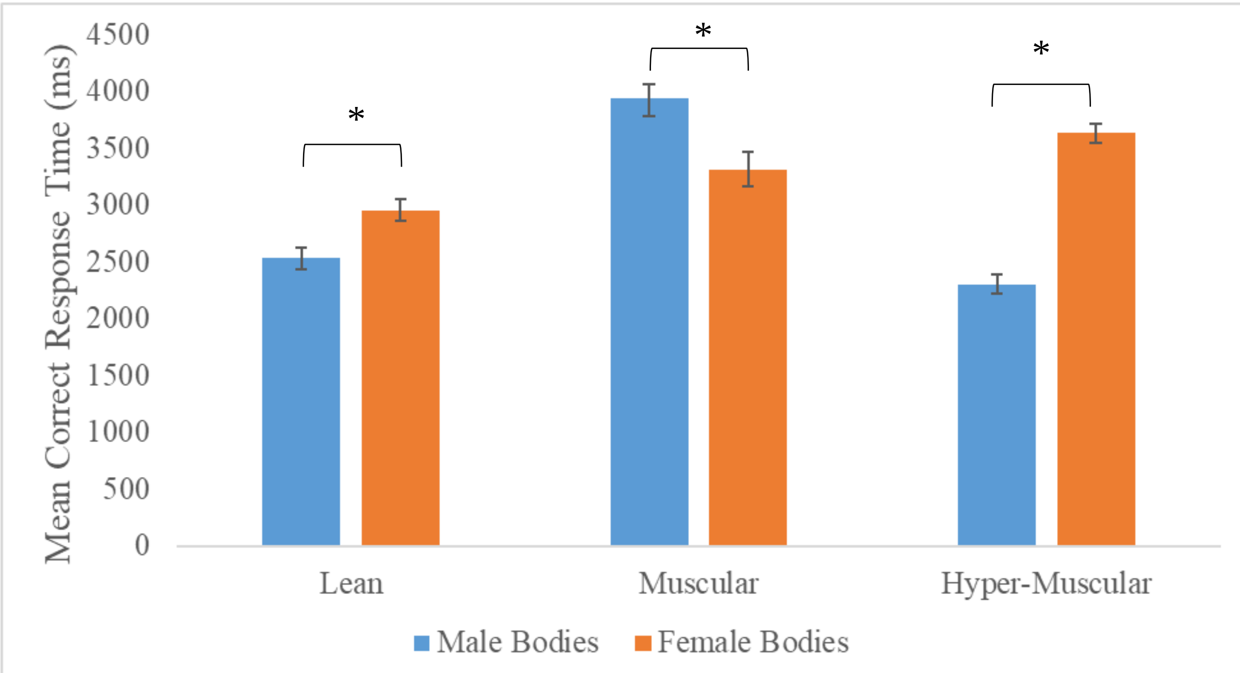



Figure 37. Mean Response times (ms) across conditions of body dimension and body gender. Error bars depict standard error of the means, and asterisks indicate significant pairwise comparisons (p <.05).

## Body Part Estimation Task

On average, participants over-estimated upper body width (arm width) and lower body width (leg width), and under-estimated body height (see Table 21). Both muscular and hyper-muscular men's upper bodies were estimated to be broader than women's bodies, while muscular women's lower bodies were estimated to be broader than men's bodies. Both muscular and hyper-muscular women's bodies were e3stimated to be larger than men's bodies in height. Average estimation error on the horizontal (x) and vertical (y) plane were similar across body dimensions and genders.

Table 21 Mean estimation (standard deviation in parentheses) on the body part estimation task (measured in pixels)

| Body dimension | Lean | | Muscular | | Hyper-Muscular | |
|---|---|---|---|---|---|---|
| Body gender | Male | Female | Male | Female | Male | Female |
| Arm Width | 72.46 (44.25) | 71.69 (43.30) | 102.54 (47.04) | 67.11 (45.25) | 81.90 (44.67) | 75.87 (43.46) |
| Leg Width | 64.11 (40.19) | 63.91 (40.08) | 53.16 (26.87) | 63.05 (40.19) | 51.46 (27.57) | 49.50 (28.46) |
| Body Height | 78.27 (29.87) | 76.91 (31.40) | 58.75 (25.83) | 77.14 (33.28) | 61.36 (29.80) | 76.96 (31.26) |
| X discrepancy | 55.25 (25.02) | 55.79 (35.18) | 55.44 (36.15) | 55.04 (34.85) | 55.68 (35.26) | 55.41 (35.70) |
| Y discrepancy | 53.66 (33.15) | 54.28 (33.44) | 52.35 (31.58) | 54.67 (33.43) | 53.45 (32.51) | 53.72 (33.75) |

*Note.* Arm width = left arm axis estimate – right arm estimate**;** Leg width = left leg estimate – right leg estimate**;** Body height = Chest estimate – average leg estimate. *n* = 706. *SD*

## Correlations

Measured variables were either entered into parametric (Pearson's) or non-parametric (Spearman's) correlations depending on whether they were normally distributed or not. Results of the Pearson's correlations (see Table 22) indicated that there was a small but significant negative association between average correct response time and body dysmorphia symptomology, such that increased dysmorphic concern as measured by the BICI related with faster response times in selecting body parts of the correct dimension. The correlation held true for both male ($r$ (706) = -0.087, $p < .001$) and female body stimuli ($r$ (706) = -0.090, $p < .001$), suggesting that dysmorphic concern systematically relates to improved feature-based processing for all bodies. The associations between average correct response times and MD symptomology were in the same direction but not significant ($r$ (706) ≤ -0.060, $p > .05$), suggesting correct response time was unrelated to MD symptomology in the overall participant sample. Response accuracy was not related to any of the body image disturbance measures.

Table 22 Pearson's *r* Correlation values for the body concerns severity and the tasks variables.

| Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1. EDI-3 | - | | | | | | |
| 2. BICI | .636** | - | | | | | |
| 3. MDDI | .377** | .569** | - | | | | |
| 4. Mean Accuracy male bodies | .029 | -.001 | -.020 | - | | | |
| 5. Mean Accuracy female bodies | -.002 | -.045 | -.039 | .373** | - | | |
| 6. Mean RT male bodies | -.051 | -.087* | -.053 | -.022 | .020 | - | |
| 7. Mean RT female bodies | -.048 | -.090* | -.060 | -.028 | -.021 | .396** | - |
| 8. Body Height male | -.008 | -.030 | -.047 | .006 | .019 | -.003 | .007 |

*Note.* * $p < .05$, ** $p < .001$

Results of the Spearman's correlations can be seen in Table 23. They show that estimates of arm width, leg width, and body height, as well as overall error in location estimation of body parts along horizontal (x) and vertical (y) axes, were also not associated with any of the body image disturbance measures in the overall sample, with one exception. Error in estimating the location of male body parts along the vertical axis (y) showed a small, negative correlation with EDI body dissatisfaction (r (706) = -0.083, p < .05). This suggests that increased body dissatisfaction systematically related to lower error in estimating vertical spatial location of body parts for male bodies only.

Table 23 Spearman's *r* Correlation values for the body concerns severity and the tasks variables.

| Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. EDI-3 | - | | | | | | | | | | |
| 2. BICI | .633** | - | | | | | | | | | |
| 3. MDDI | .439** | .588** | - | | | | | | | | |
| 4.Arm Width Male | .023 | .014 | .011 | - | | | | | | | |
| 5.Arm Width Female | .010 | .012 | .018 | .774** | - | | | | | | |
| 6. Leg Width Male | -.023 | -.064 | -.045 | .478** | .513** | - | | | | | |
| 7. Leg Width Female | .013 | -.016 | -.006 | .478** | .465** | .748** | - | | | | |
| 8. Body Height Female | .008 | -.014 | -.027 | -.187** | -.213** | .022 | .033 | - | | | |
| 9. Mean Error Male X axis | .038 | .015 | .019 | .224** | .182** | .287** | .370** | -.021 | - | | |
| 10. Mean Error Male Y axis | -.083* | -.068 | -.059 | -.026 | -.067 | .008 | -.008 | .121** | .048 | - | |
| 11. Mean Error Female X axis | .019 | -.001 | .007 | .180** | .183** | .281** | .271** | -.052 | .797** | .005 | - |
| 12. Mean Error Female Y axis | -.051 | -.070 | -.036 | -.020 | -.071 | .046 | -.002 | .121** | .068 | .757** | .016 |

*Note.* * *p* < .05, ** *p* < .001

**Correlations in male participants**

Results of the Pearson correlation (see Table 24) indicated that there was no association of average correct response time, accuracy, and male body height estimation with body dissatisfaction, dysmorphic concern, or MD symptomology in men. Spearman's correlations (see Table 25) showed that the same was true for arm width, Leg width, and body height estimations, as well as for error in location estimation of female body parts along horizontal (x) and vertical (y) axes. However, error in spatial estimation of male body parts was associated with some body image disturbance measures. Specifically, greater body dissatisfaction related to less error in estimating locations along the vertical axis (y) (r (214) = -.156, p < .05), while greater MD symptomatology related to less error in estimating locations along the horizontal axis (x) (r (214) = -.142, p < .05). This suggests that men who are more at risk of muscle dysmorphia are better at judging horizontal placement of body parts for bodies of their own sex, and men with more body dissatisfaction are better at judging vertical placement for such body parts.

Table 24 Pearson's *r* Correlation values for the body concerns severity and the tasks variables in men.

| Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1. EDI-3 | - | | | | | | |
| 2. BICI | .572** | - | | | | | |
| 3. MDDI | .399** | .679** | - | | | | |
| 4. Mean RT male bodies | -.023 | -.094 | -.022 | - | | | |
| 5. Mean RT female bodies | -.031 | -.110 | -.009 | .477** | - | | |
| 6. Mean Accuracy male bodies | -.069 | -.059 | -.081 | .026 | -.039 | - | |
| 7. Mean Accuracy female bodies | -.021 | .087 | -.007 | -.005 | -.002 | .384** | - |
| 8. Body Height male | -.024 | -.062 | -.068 | .051 | .015 | .005 | -.026 |

*Note.* * *p* < .05, ** *p* < .001

Table 25 Spearman's *r* Correlation values for the body concerns severity and the tasks variables in men.

| Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. EDI-3 | - | | | | | | | | | | |
| 2. BICI | .598** | - | | | | | | | | | |
| 3. MDDI | .515** | .668** | - | | | | | | | | |
| 4.Arm Width Male | .001 | -.069 | -.067 | - | | | | | | | |
| 5.Arm Width Female | -.001 | -.092 | -.076 | .767** | - | | | | | | |
| 6. Leg Width Male | .002 | .034 | -.069 | .537** | .493** | - | | | | | |
| 7. Leg Width Female | .061 | .098 | -.056 | .506** | .493** | .754** | - | | | | |
| 8. Body Height Female | -.018 | -.057 | -.015 | -.159* | -.185** | -.061 | -.048 | - | | | |
| 9. Mean Error Male X axis | .038 | -.067 | -.142* | .201** | .137* | .295** | .437** | .050 | - | | |
| 10. Mean Error Male Y axis | -.156* | -.054 | -.053 | -.115 | -.119 | -.030 | -.077 | .056 | .036 | - | |
| 11. Mean Error Female X axis | .013 | -.036 | -.088 | .187** | .178** | .296** | .363** | .033 | .811** | -.002 | - |
| 12. Mean Error Female Y axis | -.059 | -.113 | -.052 | -.054 | -.118 | .034 | -.055 | .108 | .041 | .816** | -.019 |

*Note*. * $p < .05$, ** $p < .001$

### Correlations in female participants

Results of the Pearson's correlations (see Table 26) indicated that there was a negative association between average correct response time and dysmorphic concern, which held true for both male bodies (*r* (487) = -0.114, *p* < .05) and female bodies (*r* (487) = -0.103, *p* < .05). This suggests that the finding of faster selection of body parts of the correction dimension in the overall sample was largely driven by our female participants. In addition, there was a negative correlation between lower selection accuracy for female body parts and increased body dysmorphic concern (*r* (487) = -.106, *p* < .05). Therefore, in women with higher dysmorphic concern the increase in speed on trials where the correct body part was selected was accompanied by an increase in the number of (other) trials where mistakes were made. Spearman's correlations (see Table 27) showed that there were no systematic associations of body image disturbance with arm width, leg width, or body height estimations, or with error in location estimation of female body parts along horizontal (x) and vertical (y) axes. However, greater MD symptomatology related to more error in estimating locations along the horizontal axis (x) (r (214) = .101, p < .05). This suggests that women who are more at risk of muscle dysmorphia are worse at judging horizontal placement of male body parts.

Table 26 Pearson's *r* Correlation values for the body concerns severity and the tasks variables in women.

| Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1. EDI-3 | - | | | | | | |
| 2. BICI | .588** | - | | | | | |
| 3. MDDI | .455** | .639** | - | | | | |
| 4. Mean RT male bodies | -.075 | -.114* | -.066 | - | | | |
| 5. Mean RT female bodies | -.063 | -.103* | -.084 | .384** | - | | |
| 6. Mean Accuracy male bodies | .068 | .025 | .017 | -.034 | -.025 | - | |
| 7. Mean Accuracy female bodies | .003 | -.106* | -.059 | .027 | -.028 | .367** | - |
| 8. Body Height male | .002 | -.013 | -.037 | -.015 | .004 | .006 | .039 |

*Note*. * *p* < .05, ** *p* < .001

Table 27 Spearman's *r* Correlation values for the body concerns severity and the tasks variables in women.

| Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. EDI-3 | - | | | | | | | | | | |
| 2. BICI | .573** | - | | | | | | | | | |
| 3. MDDI | .473** | .635** | - | | | | | | | | |
| 4.Arm Width Male | .031 | .043 | .047 | - | | | | | | | |
| 5.Arm Width Female | .027 | .059 | .064 | .778** | - | | | | | | |
| 6. Leg Width Female | .008 | -.071 | -.037 | .455** | .524** | - | | | | | |
| 7. Leg Width Female | .031 | -.028 | .022 | .469** | .454** | .743** | - | | | | |
| 8. Body Height Female | .023 | .005 | -.035 | -.200** | -.223** | .058 | .067 | - | | | |
| 9. Mean Error Male X axis | .027 | .048 | .101* | .235** | .204** | .281** | .337** | -.058 | - | | |
| 10. Mean Error Male Y axis | -.053 | -.048 | -.061 | .014 | -.042 | .021 | .018 | .146** | .056 | - | |
| 11. Mean Error Female X axis | .019 | .014 | .056 | .180** | .186** | .271** | .228** | -.092* | .788** | .009 | - |
| 12. Mean Error Female Y axis | -.055 | -.051 | -.030 | -.010 | -.051 | .048 | .018 | .123** | .078 | .734** | .030 |

*Note.* * $p < .05$, ** $p < .001$

# Discussion

We used the visuospatial body map task to implicitly assess the body image in a large sample of adults. The visuospatial body map task asks participants to estimate the position of one body part relative to other body parts, based on an image of a body. Our results reveal several insights into the body image. First, we found that increased body image disturbance, specifically with regard to dysmorphic concern, was associated with increased speed in visuospatial body map choice task performance, which closer inspection revealed to be the case in female participants only. At the same, and for female participants only, we also found that increased dysmorphic concern was also associated with reduced accuracy in the choice task. That is, women with greater dysmorphic concerns were both faster and less accurate at choosing a body part of the correct size within our task than women with fewer concerns. In line with this, greater dysmorphic concern was also related with more error in estimating the spatial location of male body parts along the horizontal axis in women. Secondly, we found that measures of body image disturbance in our male sample related to spatial location estimation of male body parts only. Specifically, MD symptomatology related to improved localisation along the horizontal axis, while body dissatisfaction related to improved placement along the vertical axis. Finally, the body map task also revealed some interesting findings when considering the aspect of performance (especially body width estimation) that did not relate to measures of body image disturbance.

The visuospatial body map task was originally inspired by Daurat-Hmeljiak et al.'s “Body Scheme Task”. In their task, participants place nine tiles of body part images (neck, left and right torso, arm, hand, and leg) on a sheet with an image of a head (Daurat-Hmeljiak et al., 1978). Importantly, the visuospatial body map task presented in the present study allows a quantitative analysis of overall body size. Each part location is identified from its x and y pixel coordinates, and size can be inferred from the distance between original and estimate coordinates. Previous uses of test like this were largely confined to qualitative comments about the lack of alignment and integration between judgements of different body parts (Daurat-Hmeljiak et al., 1978).

Moreover, as our visuospatial body map task employs multiple trials, it was possible to average multiple repetitions per part, providing more accurate estimates of body configural processing compared to the "Body Scheme Task" (Daurat-Hmeljiak et al., 1978).

We predicted increased levels of body image concern would predict increased visuospatial body map task performance on measures that indicate enhanced feature-based body-structural processing (H1). In line with our hypothesis, we found that increased dysmorphic concern in women was associated with increased task performance in terms of speed. This suggests improved feature-based processing (rapidly selecting the correct body part from among three different sizes) among women with more subclinical symptoms of body image disturbance. This extends similar findings made for women and adolescent girls at risk of body image disturbance (Groves et al., 2020; Mundy & Sadusky, 2014) and women with eating disorders (Urgesi et al., 2012) but shows it for a different task. It is of interest to note that this was not specific to bodies of the same sex as the participants' but was true for both male and female bodies.

For greater dysmorphic concern, we also found that the increase in speed on trials where the correct body part was selected was accompanied by an increase in the number of trials where mistakes were made. This suggests a somewhat more unstable performance as body dysmorphic concerns increase. Reduced task accuracy in women with heightened BDD symptoms may be explained by attending to or monitoring of body part defects during some trials of the task rather than attending to potential differences in body part size/shape as required (Phillips, Didie, Feusner, & Wilhelm, 2008). Increased feature-based processing is a general characteristic of body image disturbance, which is why on many trials, those with increased BICI scores showed improved speed of correct selections. However, an excessive focus on flaws within body parts is specifically characteristic of BDD, which is one reason why BDD is classed as an obsessive-compulsive disorder within the DSM-V. If those with increased BDD symptomology where more prone to monitoring defects instead of focusing on the task at hand, it may explain why they also make mistakes more often.

As predicted (H1), we also found that location estimation performance related to measures of body image disturbance in some conditions. Error in male body part location estimation overall systematically related to MD symptomatology in men and women, and to body dissatisfaction in men. More specifically, improved location estimation of body parts on the horizontal axis was found to be associated with greater MD symptoms, suggesting that person with elevated symptoms were better at horizontal spatial estimation of individual bodily features. Men (but not women) with more body dissatisfaction were better at vertical spatial estimation of bodily features. These findings are in line with those for correct body part selection speed and thus provide further support for the hypothesis that improved feature-based selection is characteristic of heightened body image disturbance.

Other previous studies have explored the perception of body size, largely focusing on body width. Female control groups have been found to both accurately estimate their body width (calliper adjustment technique: Slade and Russell, 1973) and overestimate their body width (adjustable light beam: Thompson & Spana, 1988). Also, other studies adopting different methodological techniques have found that females overestimate waist and hip width (moving calliper technique: Gleghorn et al., 1987) and abdomen and pelvis width (image marking procedure: Molinari, 1995). A recent meta-analysis of studies inducing body image distortions through full body illusions in virtual reality found that shoulder and hip circumference are the most affected body metrics in women (Turbyne et al., 2021). For the present study estimates of body width were indirectly acquired from estimates of individual body part positions. Contrary to hypothesis (H2) and previous research (Daurat-Hmeljiak et al., 1978; Spitoni et al., 2015), we found that over-estimation of body width on the visuospatial body map task was unrelated to measures of body image concern (H2). This shows that both males and females with increased body dysmorphic concerns do not over-estimate body width, which indicates intact configural processing despite greater body dysmorphic concerns. Our sample of healthy and subclinical men and women therefore differ from most clinical and recovered female samples in the literature (Beilharz et al., 2016; Duncum et al., 2016; Feusner, Moller, et al., 2010; Groves et al., 2020; Mundy & Sadusky, 2014; Turbyne et al., 2021; Urgesi et al., 2012; 2014; but see Slade and Russell, 1973). The reported absence of relationships between body width estimations and body image concern measures in men is perhaps less surprising. Previous research has suggested that, in general, males overestimate body size, but do so significantly less than non-clinical women (Keeton, Cash, & Brown, 1990; Thompson & Thompson, 1986). Interpreting the result of body size overestimation among women is straightforward given that they desire thinner bodies (Oehlhof, Musher-Eizenman, Neufeld, & Hauser, 2009), they overestimate because they are dissatisfied, and they believe that they are larger than they actually are. With males, interpretation is more problematic because body composition is more salient than body size, and it is not known what aspect of body composition is driving the misperception: muscles or body fat. Despite body size accuracy being relevant in women because they generally desire thinner bodies, it is difficult to suggest that size is as important to males because their body ideal is possibly not as unilateral (Grieve, 2007). Given that the socialised male body ideal is composed of high degrees of muscularity and low degrees of body fat (Leit et al., 2001; Pope Jr et al., 1999), the polar effects of these two components of appearance lead to the absence of a particular body size that is necessarily associated with the male body ideal, which may explain why we found body estimations to be unrelated to all body image concern measures in men. Therefore, perception of body size accuracy in males is likely to have greater variability than women and based on individual factors, one's own body type, and body ideal (Cafri & Thompson, 2004). Specifically, the measures of perceptual accuracy in this study did not fully consider both aspects of male appearance. Therefore, measures which comprise of both body composition and body size to body perception should be encouraged in future studies.

We found that estimated body length on the visuospatial body map task was unrelated to body image concern (H3). Similar research employing a different variation of the Body Scheme Task found no difference in the perceived body length between AN patients and healthy controls (Spitoni et al., 2015). This present study used body image related concerns measures that only assessed concerns towards body size and shape, and not specifically measuring concerns related to body length (e.g., short stature), which may be more pertinent in men (Gupta, Schork, & Dhaliwal, 1993; Talbot & Mahlberg, 2021). Therefore, it may be worthwhile including questions related to height in a body image measures that are specific for men.

Overall, these findings provide some support for the influence of body image on body structural encoding in the visual system, which appears to be brought to the fore by different measures of the body maps task for men and for women.

## Conclusions and future directions

Despite some inconsistent findings, this study has provided a novel online approach to body representation in populations at-risk of body-image related disorders. The present study has demonstrated that both increased (correct selection speed) and decreased (reduced accuracy) visuospatial body map task performance was associated with increased body image disturbance in women. Increased visuospatial body map task performance (body part location estimation) was associated with increased body image disturbance also in men, for whom the improved localisation of same-sex body parts in the horizontal plane may be highlighted as a potential marker of MD symptomology. Furthermore, this present study found no evidence for reduced configural processing (body width / height estimations) in those with elevated body image concerns. This study has implications for understanding the extent body representation can be used to assess body image concerns in the general population. This task measures body-featural processing performance (body part selection and localisation) separately from body configural processing performance (body width / height estimations), demonstrating the importance of developing protocols which assess body structural encoding and how it may be distorted in people with body image disorders.

As MD is a body image disorder which encompasses preoccupation with insufficient muscularity, future research could consider estimation discrepancies beyond body width and length, such as muscularity size and muscularity definition estimation discrepancies, which may provide greater insight into body representations amongst those at-risk of MD. Future research could also embed eye-tracking methods to this task to better understanding what areas of the body and body parts the participants are attending to in order to guide their choice responses and estimations. In terms of clinical implications, recent research has shown potential for interventions that maximize the use of afferent somatosensory information to recalibrate visual body metric representation (Caggiano, Bertone, & Cocchini, 2021). Future studies could consider incorporating a variation of recalibration training into our visuospatial body map task as an alternative to measuring body metric representations. Finally, this task could be adapted to assess body representation in other body image related disorders, such as height dysphoria.

# Chapter 6 A proposed flicker paradigm study for assessing attentional bias towards body and supplement information processing in gym-goers at-risk of muscle dysmorphia


## Abstract

The primary purpose of the present proposed study is to investigate attentional biases for bodies, muscle building supplements, and gym equipment in gym-goers with high and low risk muscle dysmorphia (MD) using a flicker paradigm. Specifically, this proposed study will examine whether attention allocation processes differ between gym-goers with high and low risk of MD using transient changes of bodies, supplements, gym-equipment, and neutral picture elements. For performance during the flicker task, we expect to find an interaction effect between risk group, stimulus type and participant gender. Specifically, we expect attentional bias effects from MD-relevant images (depicting bodies, food supplements, gym equipment) to be larger than those from less relevant (neutral) images in High risk MD men and High risk MD women but comparable in size in Low risk MD men and Low risk MD women. This would suggest High risk MD gym-goers show enhanced attentional bias effects for MD-relevant stimuli in comparison to Low risk MD participants, and that these effects would be largest toward bodies of their own gender. Such findings could provide a rationale for the application of attentional bias modification training and body exposure in patients with clinically relevant body image concerns. This study is presented here as a planned experiment only because of time and budget constraints resulting from COVID-19 restrictions.

# Introduction

Visual perception is affected by not only image saliency but also personal knowledge biases (Cho & Lee, 2012; Gregory, 1997). The perception and subsequent emotional appraisal of one's own body is similarly mediated by our personal beliefs regarding body image. In extreme cases, such beliefs may be distorted and lead to recognised mental disorders such as body image related disorders and eating disorders (ED) (Cordes et al., 2017; Gao et al., 2011; Griffiths et al., 2014; Waldorf et al., 2019). However, the mechanisms underlying the development and maintenance of these disorders are less understood. Cognitive theories of body dissatisfaction suggest that schemas related to appearance, shape, and weight influence the processing of information about body image (Cash & Labarge, 1996; Williamson, White, York-Crowe, & Stewart, 2004). Where an overconcern with body size/shape can result in a body self-schema that is readily activated by external and internal cues. This self-schema is presumed to direct the person's attention to body- and food-related stimuli and to bias interpretations of self-relevant events in favour of fatness interpretations (e.g., feelings of fullness may be interpreted as "feeling fat." Similarly, innocuous comments from others may be interpreted as negative evaluation of one's body size, or shape) (Williamson et al., 2004)

Thus, body image schemas may be accompanied by a number of biases that can guide selective attention to, or processing of, body image information in the environment. Therefore, cognitive biases may play an important etiological role in the development and maintenance of body dissatisfaction and associated body image related disorders (Cash & Labarge, 1996, Williamson et al., 2004).

Body dissatisfaction, especially concerning muscularity, has been found to be associated with adverse psychological and behavioural consequences such as low self-esteem, depression, exercise dependence, eating pathology, and the abuse of anabolic-androgenic steroids (e.g., Chittester & Hausenblas, 2009; Hildebrandt et al., 2012; Olivardia et al., 2004). An excessive drive for muscularity is also a core component of MD, a body image disorder (Pope, et al., 1997) characterised by the persistent and pathological belief that one's body is insufficiently muscular and lean (Olivardia, 2001). Although in the DSM–5, MD has been classified as a subtype of BDD (American Psychiatric Association, 2013), it has been shown to share several phenomenological features with AN (see Murray et al., 2010), including excessive body shape and weight concerns, obsessive exercising (Murray et al., 2012), and perfectionism (Davis & Scott-Robertson, 2000). Research on etiological and maintaining factors of body dissatisfaction, drive for muscularity, and MD might thus benefit from the application of models of EDs to MD. The cognitive-behavioural model of ED (Williamson et al., 2004) suggests that in people with disturbances of the body image and eating behaviours, activating events can trigger a maladaptive, appearance-related self-schema, constructed over time on the basis of an individual's learning experiences. This self-schema results in a cycle of cognitive biases and subsequent maladaptive cognitions, emotions, and behaviours, which reinforce the cognitive biases (Markus, Hamill, & Sentis, 1987). Attentional biases are key among these biases because there is lots of incoming information and we can only process so much at once, is it necessary for an individual to selectively filter incoming information (Yiend, 2010).

Several studies have examined information processing biases in women who typically desire thin bodies (Cho & Lee, 2012; Gao et al., 2011; Joseph et al., 2016). Individuals with EDs were shown to have a decreased likelihood of visually fixating on their own "beautiful" body features and have an increased frequency of fixating on their “ugly” body features (Jansen, Nederkoorn & Mulkens, 2005; Roefs et al., 2008), suggesting self-schema plays a role in focusing attention on specific aspects of visual information. The opposite pattern (predominantly focusing on “beautiful” and less on “ugly” body features) is true when ED women view others’ bodies. Similar attentional biases toward body features can be seen in men. Previous studies using well-established attentional bias methods, such as visual probe tasks and eye tracking, have observed specific body-related attentional bias towards idealised thin and muscular bodies over other types of body sizes or neutral images in men with high body dissatisfaction (Cho & Lee, 2012; Cordes et al., 2016; Cordes et al., 2017; Joseph et al., 2016). Similar results were found among men at high risk of developing MD (Jin et al., 2018), who found that in adult Chinese men at higher risk of MD displayed biases in orienting and maintaining their visual attention toward images of bodybuilders, and these biases facilitated their information processing. In summary, results on body-related attentional bias in men indicate that there are attentional biases towards muscular bodies over other body types. There is also evidence suggesting that, similar to women with EDs, men with heightened MD symptoms show attentional bias towards self-reported “unattractive” body parts (Waldorf et al., 2019) and muscle-related areas of interest (e.g., chest and shoulders) (Porras-Garcia, Exposito-Sanz, Ferrer-Garcia, Castillero-Mimenza, & Gutiérrez-Maldonado, 2020; for a review see Talbot & Saleme, 2022). Therefore, one possible mechanism underlying the association between attentional bias towards muscular bodies and body dissatisfaction is that increased attention to muscularity results in more frequent upwards (unfavourable) appearance comparisons with others, which in turn exacerbate insufficient muscularity rumination, which in turn increases body dissatisfaction.

In the field of body image and body-related attentional bias, several differing approaches have been used to measure different attentional processes (Talbot & Saleme, 2022). Some of these approaches focus on reaction-time measures, such as the Stroop Task and the Visual-Probe Task. The Stroop task relies on single word presentations (negative body shape/weight target words (e.g., "fat"), neutral target words (e.g., "car"), or negative emotion target words (e.g., "hate")) and therefore provides only a limited representation of what might, in real life, give rise to the attentional bias. A photograph of a body may provide a richer, more ecologically valid representation than single words, as they are more indicative of the real-life experiences that nurture the cycle of cognitive biases and maladaptive behaviours. The visual-probe task involves a pair of stimuli presented simultaneously on different sides of a computer screen followed immediately by a visual probe, which replaces one of the stimuli. Faster response times to the probe that appears in the previous location of a stimulus (e.g., muscular body) compared to a neutral stimulus (e.g., car exterior) are suggested to indicate the existence of attentional bias. However, eye-tracking studies have revaluated that this task is limited in its ability to assess attentional bias because some participants showed a tendency to ignore all the stimuli displayed during the task and to initiate their search only when the probe appeared (Brooks et al., 2011).

## Change blindness as a paradigm for detecting muscle dysmorphia

Change blindness (Simons and Levin 1997; Simons & Rensink 2005) refers to observers' scarce ability to detect changes made to scenes or images when those changes are contingent with a brief disruption in visual continuity (Simons, 2000). An established method of inducing change blindness is using the "flicker paradigm", in which brief transient screens are inserted between two presentations of images which differ only for a modified detail (A→A'). This transition creates a global motion signal that overlaps with the localised signal associated with the change, making it remarkably difficult to detect even when it is very large (Rensink, O'Regan, & Clark, 1997). This alternation is carried out until the observer identifies the change. However, the perceiver's ability in detecting (or not detecting) the change in the presence of a visual disturbance depends on several factors. Specifically, the information potential (IP; Bracco & Chiorri, 2009) of the changing element is of central importance. The IP is generally defined as the informativeness level of a target in a scene and derives from the joint effects of bottom-up saliency and top-down relevance. Of particular relevance to the present work, some studies (Bracco & Chiorri 2009; Ro et al. 2001) demonstrated that changes in elements holding high IP (e.g., people, faces) are easier to detect than changes in elements holding low IP (e.g., irrelevant objects) regardless of other aspects of the changing element, such as its salience or position in the scene. Studies using the flicker paradigm have also demonstrated that change detection is superior for more meaningful aspects of a scene, indicating that high-level knowledge affects how attention is allocated (see Rensink, 2002, for a review). Rensink, O'Regan, and Clark (1997) found changes that independent raters deemed to be of "central interest" in naturalistic scenes were more readily detected than those deemed to be of "marginal interest", indicating that attention is allocated to the most important aspects of a scene first. Changes in objects of central interest involve the meaningful portion of the images, and they are usually detected efficiently (Rensink, 1997). Changes in objects of marginal interest are harder to detect and require a serial visual search. In this case, performance is generally less efficient. Therefore, the flicker task would measure attentional bias for salient target stimuli that capture attention, overcoming limitations of both the Stroop and the visual probe tasks (Jones, Stacey, & Martin, 2002). Moreover, this paradigm could assist in the analysis of both automatic and voluntary components of attention, due to the movement of focused attention in the environment (e.g., Jonides, & Irwin, 1981; McGlynn, Wheeler, Wilamowska, & Katz, 2008; Posner, Snyder, & Davidson, 1980). Where the salience of a visual stimulus influences the externally originated or automatic orienting of the attention, while the subject's goals drive the internally originated or voluntary orienting of attention (Làdavas, Carletti, & Gori, 1994; Turatto, & Galfano, 2000).

In the present study, we used a change blindness flicker paradigm to further investigate the cognitive bias involved in male and female gym-goers at risk of MD. We assume that on-body changes would be noticed more quickly than off-body changes overall, as we expect bodies to hold a greater IP than non-body objects. According to this rationale, we also would hypothesise that on-body changes (higher IP) would be detected quicker than off-body (lower IP) changes in participants with High risk MD symptomology in comparison to participants with Low risk MD, especially in bodies that are more MD-relevant (same-sex vs. opposite-sex bodies, less clothed vs. more clothed). All bodies were depicted in an exercising context. We expected similar effects for muscle building supplements: changes on muscle building foods/supplements (higher IP) would be detected quicker than changes off muscle building foods/supplements (lower IP) in those with heightened High risk MD symptomology compared to Low risk MD. Furthermore, we expected changes on gym equipment (higher IP) would be detected quicker than changes off gym equipment (lower IP) in those with High risk MD symptomology compared to Low risk MD. No such patterns were expected for changes on vs. off items of central interest within mages of non-muscle building foods/supplements and of non-gym equipment (similar IP for all participants). We further hypothesise that the size of each MD-relevant attentional bias (bodies, supplements, gym equipment) will positively correlate with measures of body dissatisfaction, disordered eating towards muscle-oriented foods, and appearance and performance enhancing supplement usage.

# Materials and methods

## Participants

Participants will be recruited via pre-existing databases, social media platforms, and University of Essex mailing lists. A £10 Amazon gift card will be offered as an incentive to participate. Participants will be required to be aged between 18 and 65 years, and have been exercising regularly using resistance (e.g., weights, bodyweight, resistance bands) as part of their exercise regime for at least the last six months prior to their participation. This was to ensure that resistance training was an established aspect of their regular gym routine. Participants can only participate using a laptop/PC; this is mainly due to responses being measured via mouse clicks which could not be achieved via mobile phone or tablet. Similar to Chapter 2, a median split of the scores on the MDDI (Hildebrandt, Langenbucher, & Schlundt, 2004) will be used to determine assignment to either the High risk MD group or the Low risk MD group. To avoid too many participants with low MD symptomology being recruited, initial recruitment will involve participants with high MD symptomology from a pre-existing database first. Using G*Power for an a priori power analysis, for a mixed analysis of variance (MANOVA) repeated measures within-between interaction, a Cohen (1988) *f* of 0.5 (i.e., a medium effect size), and a power estimate of 80%, the recommended sample size is a minimum of 30 participants.

## Exclusion Criteria

Individuals who had been diagnosed with body dysmorphic disorder and/or eating disorder will not be recruited. Those who had experienced a major psychiatric disorder, such as schizophrenia or bipolar disorder, will also not be permitted to participate. We chose not to recruit participants who had a medical diagnosis or a history of mental illness, to ensure the groups differed as little as possible in terms of mental health.

## Ethical Declaration

The study was approved by the local Ethics Committee for the Psychology Department at the University of Essex (Ethics ID: ETH1920-1045).

## Apparatus and Stimuli

## Questionnaire Measures

### Muscle Dysmorphia Disorder Inventory (MDDI)

The Muscle Dysmorphia Disorder Inventory (MDDI) (Hildebrandt, Langenbucher, & Schlundt, 2004) will be used to measure MD symptomology (see Chapter 2 of this thesis for full details).

### New Somatomorphic Matrix - Male (NSM-M) and New Somatomorphic Matrix - Female (NSM-F)

The New Somatomorphic Matrix–Male (NSM-M) (Talbot, Smith, Cass, & Griffiths, 2018) and the New Somatomorphic Matrix - Female (NSM-F) will be used to measure body dissatisfaction (see Chapter 2 (NSM-M) and 3 (NSM-F) of this thesis for full details).

### Muscularity-Oriented Disordered Eating Test (MOET)

The Muscularity-Oriented Disordered Eating Test (MOET) (Murray et al., 2019) will be used to measure eating-related behavioural and attitudinal components of muscularity-oriented disordered eating (see Chapter 3 of this thesis for full details).

### Appearance and Performance Enhancing Supplement/Substance Scale (APES)

The Appearance and Performance Enhancing Supplement subscale (APES) (Cooper, Hicks, & Griffiths, 2019 will be used to measure individual use of supplements and substances for the purpose of body modification and enhanced performance (see Chapter 2 of this thesis for full details).

### Visual Stimuli

16 pictures (500 × 500 pixels) were obtained via an online search and consisted of: eight males (four clothed, four with minimal clothing), eight females (four clothed, four with minimal clothing), 8 rooms (4 gym, 4 non-gym), and eight foods (four muscle-oriented foods, four non-muscle-oriented foods and non-foods). Each picture was manipulated using GIMP© software (ver. 2.10.30) to create an alternative version, removing or manipulating the size of one detail

from the scene (see Figure 36). Location of changes will be controlled for by making changes in each of the 4 quadrants for the 4 images pertaining to each stimulus type (see Figure 36; where changes are shown in the top left (a) and top right (b) quadrants).

(a) (b)


Figure 38. Examples of the stimuli. In half the trials, the changes were off the body/object of interest (a), and half on the body/object of interest (b). The black circle indicates which item appears and disappears during the flicker sequence.

## Procedure

We designed the experiment online using both Qualtrics (https://www.qualtrics.com) and Psytoolkit (https://www.psytoolkit.org/) (Stoet, 2010; Stoet, 2017). Firstly, participants will be asked to respond to a series of scales to measure MD symptomology (MDDI (Hildebrandt et al., 2004)), disordered eating behaviour (MOET (Murray et al., 2019)), Body dissatisfaction (NSM-M (Talbot et al., 2018), NSM-F), and supplement use (APES (Cooper, Hicks, & Griffiths, 2019)). Participants also completed questions related to general demographic information (e.g., age, sex, exercise, and dietary behaviours). All psychometric and demographic measures will be administered online via Qualtrics. Following this, participants will be instructed to participate in the change detection task via Psytoolkit (Stoet, 2010; Stoet, 2017).

Participants will be formed that they will be presented with a series of flickering images with one change and that their task was to identify where in the image the change is and to click on the location using the computer mouse as soon as possible. Before commencing the experimental change detection task, participants will undergo one practice trial in order to be familiarised with the trial procedure and response requirements (the sequence of events on each trial is depicted in Figure 37). Each trial will begin with a fixation point for 250 ms at the centre of the screen. When the fixation cross disappears, the original image and its modified version will be presented successively for 250 ms, separated by a mask for 80 ms. This series of presentation will continue until the participants detect the change (mouse clicked) or 30 seconds elapsed. All 30 second elapses will be recorded as a missed change. Response time for change detection (elapsed time between occurrence of the first change and the mouse click) will be recorded in milliseconds. To determine if participants identified the change correctly, the mouse clicks x and y pixel coordinates will be recorded for each trial. Thirty-two trials will be run in an intermixed fashion. The sequence of trials will be determined randomly for each participant to avoid displaying changes in the same position one after another.

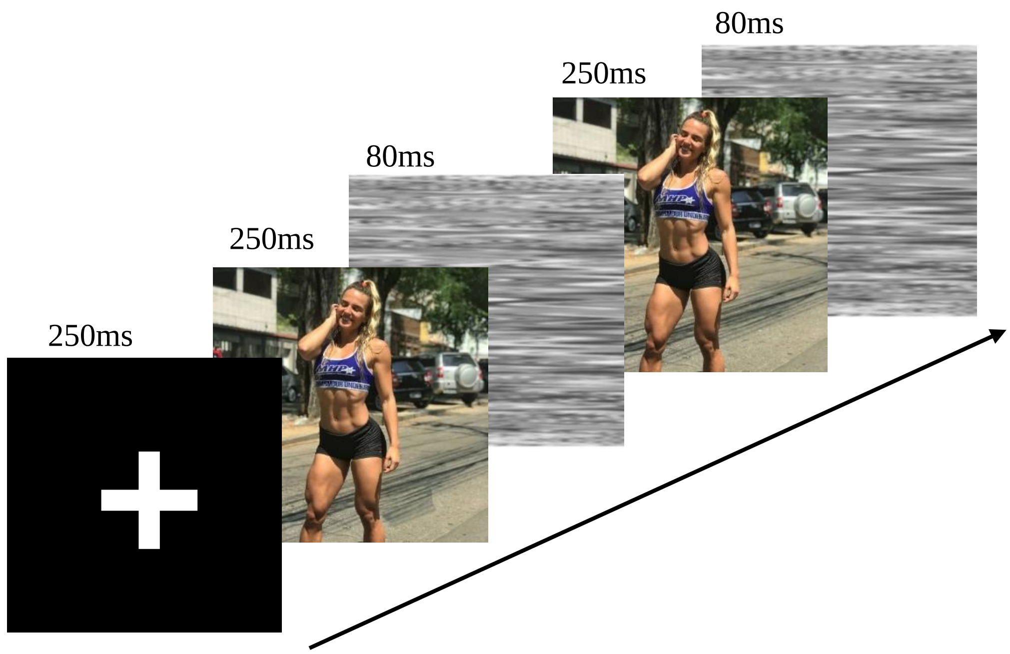



Figure 39. A schematic representation of an experimental trial used in the one-shot change detection task.

# Proposed analyses and expected results

## Data preparation

For each trial, participants' accuracy scores of change detection will be computed by assigning 1 for each correct response and 0 to incorrect responses. Responses will need to be within 10 pixels of the change location on both x and y axis's to be deemed a correct response. Response times and change detection accuracy scores will then be averaged across the different type of trials. Thus, mean scores close to 1 indicate higher levels of accuracy, mean scores close to 0 indicate lower levels of accuracy (for a similar procedure see, e.g., Boot et al., 2006). Mean scores will be calculated for responses to each psychometric measure of body image concern (MDDI, NSM-M, NSM-F), muscle oriented disordered eating (MOET) behaviour, and appearance and performance enhancing supplement usage (APES). A median split of the scores on the MDDI determined a participant's assignment to either the High risk MD group or the Low risk MD group.

## Planned Analysis

Using SPSS, descriptive statistics will be performed to understand the sample structure and study variables. T-tests will measure differences between high and low risk MD groups for demographic and questionnaire variables. To test change detection performance, we will use mixed model ANOVAs. For trials with body stimuli, change-trial scores (Accuracy) and RTs will be submitted to separate 2 (nature of change: on body vs. off body) × 2 (stimulus type: clothed vs. minimal clothing) × 2 (stimulus gender: male bodies vs. female bodies) × 2 (body image concern: low vs. high) × 2 (participant gender: male vs. female) mixed-model ANOVAs, in which the factors nature of change, stimulus type and stimulus gender will be within subject factors and body image concern and participant gender will be between subject factors.

For trials with non-body stimuli, change-trial scores (accuracy) and RTs will be submitted to separate 2 (nature of change: on object vs. off object) × 2 (stimulus type: gym equipment vs. non-gym equipment; supplement food vs. non-supplement food) × 2 (body image concern: low vs. high) mixed-model ANOVAs. The reason for conducting mixed-model ANOVAs is to assess whether changes in task performance (i.e., attentional bias) differs depending on object, nature of change and the severity of body image concern. In Chapter 2 of this thesis, image gender, body image concern, and participant gender have been shown to be significant in visual body perception, and therefore may influence task performance in this present study. If the relevant high-order effects of nature of change were significant, the attentional bias for each stimulus type would be calculated as follows:

*Male body bias effect* (RTs for detection of off-body changes in clothed/unclothed male bodies - RTs for detection of on-body changes in clothed/unclothed male bodies; Accuracy in detection of on-body changes in clothed/unclothed male bodies – Accuracy in detection of off-object changes in clothed/unclothed male bodies);

*Female body bias effect* (RTs for detection of off-body changes in clothed/unclothed female bodies - RTs for detection of on-body changes in clothed/unclothed female bodies; Accuracy in detection of on-body changes in clothed/unclothed female bodies – Accuracy in detection of off-body changes in clothed/unclothed female bodies);

*Gym equipment bias effect* (RTs for detection of off-object changes in gym equipment - RTs for detection of on-object changes in gym equipment; Accuracy in detection of on-object changes in gym equipment – Accuracy in detection of off-object changes in gym equipment));

*Muscle building food / supplement bias effect* (RTs for detection of off-object changes in supplements - RTs for detection of on-object changes in supplement foods; Accuracy in detection of on-object changes in supplements – Accuracy in detection of off-object changes in supplement foods).

The reason to calculate bias effects in this way was because we expect that certain stimuli (e.g., body parts) will draw attention. If the change occurs where participants' attention is directed (i.e., on-body change) then detection will be facilitated (lower RTs and higher accuracy), but if change occurs elsewhere (i.e., off-body change) then detection will be hindered (higher

RTs and lower accuracy). The greater a participant's attentional bias, the larger will be the difference between on- and off-body or -object changes, thus, the larger will be the bias effect.

The reason for grouping images of bodies by gender was to consider whether attention bias was gender-specific, particularly as visual perception of bodies is known to differ between genders in participants at-risk of body image disorder/s (see in Chapter 2). If no stimulus-gender effects are found, trials depicting male and female bodies will be collapsed. Further, if analyses of trials with body stimuli find an effect of stimulus type (clothed vs. minimal clothing), the above male and female body bias effects will be split into clothed and minimally clothed male and female body bias effect, respectively.

Bias effects in speed and accuracy of change detection for the different stimulus types will be correlated with all questionnaire measures (NSM-M; NSM-F; MOET; APES) to determine the extent attentional bias for MD-relevant stimuli relates to body dissatisfaction, disordered eating behaviour towards muscle-oriented foods and appearance and performance enhancing supplement usage. The false discovery rate method of correction for multiple comparisons (Benjamini & Hochberg, 1995) will be applied to correlation results, results that do not survive correction are not reported.

In line with the hypotheses of this proposal, we would expect correct RTs to be faster and accuracy to be higher for on-object changes than off-object changes (main effect of nature of change, indicating attentional bias). Further, we expect an interaction between nature of change, stimulus type (as well as stimulus gender for bodies), risk group and participant gender in each of our ANOVAs. We expect attentional bias effects to be larger for minimally clothed than clothed bodies, same sex than opposite sex bodies, larger for gym equipment than non-gym equipment stimuli, and larger for supplements than non-supplement foods in High risk men and High risk women, but comparable in size in Low risk men and Low risk women. This would suggest greater attentional bias in the High than Low risk MD groups towards MD-relevant stimulus: bodies (particularly those with minimal clothing and of the same sex as the participant), gym-equipment and muscle-building foods/supplements.

Finally, in line with the hypotheses of this proposal, we expect that an increased attentional bias effect for each stimulus type (male bodies, female bodies, gym equipment, and supplements) to positively correlate with increased body dissatisfaction, increased disordered eating towards muscle-oriented foods, and increased appearance and performance enhancing supplement usage. This would suggest a systematic relationship between MD symptomology and attentional bias toward MD-relevant stimuli.

# Discussion

The proposed study will be the first study to investigate whether attentional bias measured in terms of change blindness towards bodies, muscle building foods/supplements, and gym equipment relates to MD symptoms in both male and female resistance training gym-goers. This will be achieved by assessing task performance in a flicker (change blindness) paradigm. Based on the hypothesised positive relationship between body-related attentional bias and heightened body dissatisfaction that was asserted by Cordes et al., (2016, 2017) and measured via eye tracking, it is expected that participants at high risk of developing MD will display an enhanced body-related attentional bias effect during the flicker task in comparison to participants at low risk of developing MD. This is expected to occur because bodies hold a greater IP than non-body objects, and we expect the IP to be enhanced for participants with heightened MD, especially when bodies are displayed within an exercising context, same-sex and with minimal clothing that best indicates the depicted person's muscle mass and body fat. We further expect the same to be true for MD-relevant non-body objects such as gym equipment and muscle building foods/supplements, for which IP should be enhanced in participants with heightened MD relative to non-gym equipment and non-muscle building foods/supplements.

Observation of attentional bias effects via the flicker paradigm in individuals at-risk of MD will extend upon the recent studies that assessed, via eye-tracking, attentional bias in men with high body dissatisfaction. Previous studies demonstrated an attentional bias towards idealised bodies over other types of body sizes in men with high body dissatisfaction (Cho & Lee, 2012; Cordes et al., 2016; Cordes et al., 2017; Joseph et al., 2016), men at-risk of MD (Jin et al., 2018; Waldorf et al., 2019), and women at-risk of ED who idealise thin bodies (Ralph-Nearman et al., 2019; Roefs et al., 2008). The present study may extend upon these findings by determining whether attentional bias is present towards bodies, muscle-building supplements, gym-equipment, in both male and female resistance training gym-goers at-risk of MD, and the extent it relates to MD symptoms. As bodies, muscle-building supplements, gym-equipment, are expected to hold a higher IP and would be detected quicker than lower IP changes in participants with High risk MD symptomology, demonstrating an attentional bias effect. This research therefore has the potential to offer a cognitive explanation for why gym-goers who demonstrate increased attention towards muscular bodies, muscle-building supplements, and gym-equipment possess increased body dissatisfaction.

Previous research in women with bulimia nervosa has shown they tend to have an increased attention bias towards food, whereas women with AN tend to avoid and have a reduced attention bias towards food (for a review see Ralph-Nearman, Achee, Lapidus, Stewart, & Filik, 2019). Furthermore, Kemps et al., (2014) observed weight-related differences in attention to food versus animal words, with an attentional bias toward food (especially high-calorie) words in their obese sample (compared to healthy-weight participants). Should we find from the present study that an increased attention bias towards muscle-oriented food related to increased symptoms towards muscle-oriented disordered eating, we could further argue that, like bulimia nervosa and binge eating disorders (Williamson et al., 2004), food-related cognitive biases play a key role in the development and maintenance of muscle-oriented disordered eating.

Some important limitations should be considered. First, neither body mass index (BMI) (Roefs et al., 2008) nor drive for thinness levels (Cordes et al., 2016; Hewig et al., 2008; Janelle, Hausenblas, Fallon, & Gardner, 2003) will not be controlled for in this study, although they have been considered as important factors in body-related attention. This was designed as an online study requiring self-reported height and weight to determine BMI, which has previously been demonstrated to be an inaccurate measure because individuals tend to underestimate their BMI (Gosse, 2014), suggesting that controlling for self-reported BMI scores for this proposed study would be ineffective. Although, previous studies have found females with AN to be accurate in estimating their BMI and comparable to healthy female controls who significantly underestimated their BMI. Therefore, as we intend to recruit from a sample of resistance training gym-goers, we expect such our sample to predominantly possess a drive for size or leanness only (which were both measured in this study, alongside body dissatisfaction), their BMI estimation accuracy may differ from the general population (Mölbert et al., 2017).

It is suggested that future studies should extend on the expected finding from this study by incorporating additional eye-tracking protocols into an attentional bias flicker paradigm study. Doing so will enable researchers to examine with greater fidelity which specific body parts gym-goers at-risk of MD are visually attending to during the task, whether any attentional bias effects are specific to particular body parts, and the extent such attentional biases relate to body part dissatisfaction.

Finally, should we find an association between an attentional bias toward same-sex bodies and MD symptoms, it could provide a rationale for the application of attentional bias modification training (e.g., Smeets, Jansen, & Roefs, 2011; Renwick, Campbell, & Schmidt, 2013) and body exposure procedures (e.g., Vocks, Legenbauer, Wächter, Wucherer, & Kosfelder, 2007) in patients with clinically relevant body image concerns. For instance, using attentional bias modification to induce attentional bias toward desirable features of another's body and undesirable features of one's own body in order to observe any changes in participants' body dissatisfaction. Achieving a better understanding of the cognitive mechanisms underlying and maintaining body dissatisfaction, such as a dysfunctional body-related attention (Rodgers & DuBois, 2016), is essential to the design of future psychological ED and/or MD assessment and treatments. Clinical interventions aiming to modify body dissatisfaction may be able to draw on our expected findings in order to design specific gender-based interventions that aim to retrain dysfunctional body-related attention indifferent ways in women and men at-risk of ED and/or MD.

# Chapter 7 General Discussion

One's body image is developed and maintained via complex interactions between socio-cultural, neurophysiological, and cognitive factors: it is central to our self-concept and influences our psychology and behaviour (e.g., Stice & Shaw, 2002). Body image disturbance, such as that experienced in EDs, BDD and MD is a multi-sensory distortion to the conscious experience of the body (see Cash, 2004, 2012; Pope Jr et al., 1997). The causes of such distortions remain unclear, however, as they are underpinned and sustained by a multifaceted network of interconnected contributions from perception, cognition, affect and behaviour (e.g., De Vignemont, 2010; Feusner, Neziroglu, Wilhelm, Mancusi, & Bohon, 2010; Grogan, 2006; Stormer & Thompson, 1996; Striegel-Moore & Bulik, 2007). Nevertheless, an increasing amount of evidence indicates that the perceptual aspects of body image disturbance (e.g., fixations on perceived defects) might be related to maladapted visual processing mechanisms (see Lang, Lopez, Stahl, Tchanturia, & Treasure, 2014; Madsen et al., 2013; Suchan, Vocks, & Waldorf, 2015, for reviews). The primary aim of this thesis was to investigate the perceptual and cognitive correlates of body image disturbance, which contributes to the development and maintenance of MD and disordered eating towards muscle-oriented foods in exercising and other at-risk populations. Ultimately, the intention was to assess the extent body image disturbance can be associated with potential electroencephalographic and behavioural markers of body-related processing in exercisers and other at-risk populations. The value of this work lies in its potential for early diagnosis of those at risk of body image disturbance, given that severe psychological distress and reduced psychosocial functioning are common symptoms of MD, EDs and BDD (Olivardia, 2001, 2007; Harris & Barraclough, 1997). Thus, a series of studies were designed to examine both visual and self-reported body perception in exercisers at-risk of body image disturbance.

## Summary of major findings

The first empirical study in this thesis, presented in Chapter 2, was comprised of two ERP experiments that investigated the relationship between body image and the early temporal dynamics of body-sensitive processing in men at high risk and low risk of MD and in women at high risk and low risk of ED. The overarching aim was to identify (and replicate) potential biomarkers of MD and ED symptoms, such as body image disturbance. In the first ERP experiment, visual body-sensitive N170 and later-stage LPP components were examined in response to male- and female bodies, as well as houses (Experiment 1 only), then correlated with responses on well-established questionnaires such as the MDDI (Hildebrandt, et al., 2004) and the EDI-3 (Garner, 2004) in order to assess the relationship with body image concern symptomatology.

The first ERP experiment involved passive viewing of bodies, intended to replicate (and extend to male populations and later cortical processing stages) previously shown ERP markers of high risk for body image disturbance. We found that High risk ED women showed gender-sensitive ERP effects (larger N170 to female than male bodies) for more desirable bodies at N170, which was source localised to right occipitotemporal cortex, and found to be correlated with EDI-3 (personal alienation) in women, suggesting that such effects may reflect upward social comparisons. Low risk ED women only showed such gender-sensitive effects, which also correlated with several questionnaire measures, at later, processing stages (LPP). While Low-risk women showed gender-sensitive LPP waveforms for desirable bodies, High-risk women's LPPs were found to reflect gender-sensitive processing for less desirable bodies, which on the basis of correlations with questionnaire measures were taken to potentially index ‘fear of fatness’ in this population. While gender-sensitive N170 waveforms replicate similar findings in high-risk women by Groves et al. (2017), gender-sensitive LPPs have not been shown before, and may be an electrophysiological signature of maladaptive cognitive-emotional processing of female bodies. Both N170 and LPP amplitudes elicited by the passive viewing of bodies could therefore be considered potential biomarkers for heightened body image concerns, at least in women.

Importantly, no convincing N170 or LPP gender-sensitive effects were seen in male participants, nor did any such effects systematically relate to male body image. Our study therefore showed some clear electrophysiological differences between male and female at-risk populations, which will be discussed later in this Chapter.

In the second ERP experiment, participants indicated whether successively presented upright or inverted male and female bodies, were of the same or different identity. This task was more demanding than Experiment 1 in terms of body-structural processing mechanisms. Typical body inversion effects (faster and more accurate responses to upright than inverted bodies, and larger N170 responses to inverted than upright bodies) were seen in the Low risk groups in both behavioural (RTs, accuracy) and brain (N170) measures, whilst there was some evidence to suggest a disruption to the configural processing of body stimuli in High risk groups. We found that risk groups were characterised by larger (rather than, as expected, smaller) and gender-sensitive BIEs: behavioural BIEs were larger for male than female body stimuli in high-risk men and were statistically absent for female bodies in this group. The reverse was true for High-risk women. This suggests that atypical configural body representation typical of women at-risk of body image related disorders might extend to men at-risk of MD, and that High risk participants only show reliable (and clearly undiminished) behavioural BIEs for bodies of their own gender. This study was also the first to demonstrate that the time course of configural visual processing in populations at-risk of ED and MD differs, where gender-sensitive risk-related BIEs were replicated in ERPs (larger N170 for inverted than upright bodies) only for High risk men (see below) but were less characteristic of High risk women's ERPs. In fact, high-risk men consistently showed larger inversion effects to male than female body stimuli in both behavioural and N170 data. Gender-sensitive BIEs biased toward one's own gender may thus indicate a risk marker in men specifically, which will be discussed later in this Chapter. In addition, findings overall do not support previous suggestions that those at risk necessarily have reduced configural processing of bodies (Beilharz et al., 2016; Duncum et al., 2016; Feusner, Moller, et al., 2010; Groves et al., 2020; Mundy & Sadusky, 2014; Urgesi et al., 2012; 2014).

Moreover, our findings show that hemispheric asymmetries in N170 BIEs may be a potential biomarker of persons at risk of body image disorders, underpinned by reduced connectivity between the cortical structures related to different aspects of the encoding of the human body form. We found stronger left-than-right N170 BIEs in high risk groups, and this effect was source localised to left occipitotemporal cortex and systematically related to symptoms of eating disorder and objectified body awareness in high-risk women. Neuroimaging studies have already shown that the EBA is underactive and maladapted in those with EDs (Suchan et al., 2010, Suchan et al., 2015, Uher et al., 2005). The present results therefore add to this body of literature, providing support for the notion that cortical visual body processing is modulated by body image in men too. These findings have implications for future research looking to inform early interventions and treatment, suggesting that populations at-risk of developing body image disorders possess atypical and hemispherically asymmetric configural body processing.

In the second study, presented in Chapter 3, we conducted an online experiment which examined the relationship between interoceptive sensibility and the muscularity-oriented disordered eating among resistance-training exercisers, and to explore the mediating role of MD symptomology and appearance and performance enhancing supplement usage in this association. We found that interoceptive sensibility predicted muscularity-oriented disordered eating, and that both MD symptomology and appearance and performance enhancing supplement usage partially mediated the relationship between interoceptive sensibility and muscularity-oriented disordered eating. These findings represent the first direct demonstration that increased interoceptive sensibility systematically relates to muscularity-oriented disordered eating. Unlike previous research, which has linked lower interoceptive sensibility to eating disorder symptomology and negative body image (Ainley & Tsakiris, 2013; Brown et al., 2017; Cascino et al., 2019), our study shows the opposite in resistance training exercisers: heightened interoceptive sensibility can lead to greater pathological engagement towards muscle-oriented eating. These findings offer initial support for heightened interoceptive sensibility to be considered an additional symptom which contributes to muscularity-oriented disordered eating diagnostic criteria. Again, these findings suggest some marked differences between men and women at risk of body image disturbance, which may partially explain the differential drivers of body dissatisfaction (desire for thinness vs. desire for muscularity). This will be discussed later in this Chapter.

In the third study, presented in Chapter 4, an online experimental study was conducted which assessed the effect of gym closures and access to home gym equipment on exercise behaviour, mood disturbance, increased social media use and pressure to engage in body transformative exercising in gym members at-risk of MD and the wider UK exercise community during the COVID-19 pandemic. We found that increased MD symptoms predicted increased mood disturbance due to not being able exercise as normal, and these effects were enhanced for those with less access to home gym equipment and reduced perceptions of support from social media. We found that the reduction in time spent exercising during lockdown was markedly greater in gym members (38.1%) than non-gym members (2.5%), and greater in those with less access to home equipment to compensate for gym closures. The change in time spent exercising from pre-lockdown to during lockdown predicted the severity of mood disturbance due to not being able to exercise as normal. Despite gym closures being deemed necessary to reduce virus transmission, such closures may have contributed toward increased body dissatisfaction and body image related disorder susceptibility in those who exercise (particularly gym-members), as well as the overall increase in mental health conditions observed during the lockdown (Brooks, et al. 2020; Ingram et al., 2020). This has implications for future governmental policies relating to the availability of recreational facilities and to decisions taken about restricting their use during national crises. This will be discussed later in this Chapter.

In the fourth study, presented in Chapter 5, we investigated whether distorted body-configural representations measured by an online visuospatial body map task may be an indicator of body image concern amongst a sample from the general population. We found that increased body image concern was associated with increased task performance. Specifically, in women only, increased body-dysmorphic concern, which is characteristic of populations with EDs and BDD, was associated with quicker correct response times when selecting a previously seen body part from among several that differed in size but was also associated with decreased selection accuracy overall. This pattern of performance may be explained by attending to body 'flaws' during more trials in the encoding phase of the task rather than attending to body part size/shape (Phillips, Didie, Feusner, & Wilhelm, 2008). In men, symptoms of muscle dysmorphia and body dissatisfaction were associated with improved spatial localisation of same-sex body parts in vertical and horizontal planes, respectively. These findings suggest heightened feature-based body-structural encoding in both women and men at increased risk of body image disturbance, in line with existing literature. However, we found no evidence that configural structural encoding (measured as relative spatial relations between body parts in terms of body width and height) related to body image concern. It was concluded such findings have implications for understanding the extent to which measures of visual body representation can be used to assess body image concerns in the general population and highlights the importance of developing body representation protocols that are specific to the prevalent characteristics of each body image disorder and consider both participant and visual body stimulus genders.

In the final study, presented in Chapter 6, we proposed an online experimental study using a flicker paradigm to investigate attentional biases for bodies, muscle building supplements, and gym equipment in gym-goers with high and low risk of MD. This study plans to examine cognitive (rather than perceptual) correlates of body image disturbance. More specifically, we planned to examine whether attention allocation processes differ between gym-goers with high and low risk MD using transient changes of bodies, of supplements, of gym-equipment, and within similar neutral pictures. Change detection latencies in objects of central interest (e.g., on-body changes) compared to objects of marginal interest (e.g., off-body changes) were to be measured as an index of attention allocation. This index was expected to be heightened in high risk groups for stimuli that are more vs. less MD-relevant (same vs. opposite sex bodies with minimal vs. more clothing; muscle-building supplements vs. non-muscle-building supplements; gym equipment vs. non-gym equipment) but was not expected to be heightened in low-risk groups. This would extend previous research in women with bulimia nervosa and AN who have increased attentional biases towards food and bodies (Ralph-Nearman, Achee, Lapidus, Stewart, & Filik, 2019; Roefs et al., 2008) and men with body dissatisfaction and at risk of MD who have increased attentional bias towards idealised male bodies (Cho & Lee, 2012; Cordes et al., 2016; Cordes et al., 2017; (Jin et al., 2018; Joseph et al., 2016; Waldorf et al., 2019). To the best of our knowledge, it would add to a new paradigm (change blindness flicker paradigm) and new MD-relevant stimuli (gendered bodies, gym equipment, muscle-enhancing supplements) to existing studies of attentional bias that have used eye-tracking, visual probe, and Stroop tasks, which may be helpful for future studies examining cognitive biases and their relationship with body image. If they are as expected, our findings could provide a rationale for the application of attentional bias modification training and body exposure in patients with clinically relevant body image concerns (Smeets et al., 2011; Renwick et al., 2013; Vocks, et al., 2007).

The next sections of this chapter will continue to discuss the present thesis' main progressions in our understanding of body processing amongst exercisers and other populations at-risk of body image related disorders.

# Main progressions in our understanding of body perception amongst exercisers and other populations at-risk of body image related disorders.

## Behavioural and ERP markers of body perception differ between risk groups

Previous research has proposed that an imbalance in feature-based global processing applies to the visual perception of bodies and is thought to contribute to the abnormal, detail-specific fixation on appearance related stimuli seen in disorders marked by body image disturbance (Beilharz, Atkins, Duncum, & Mundy, 2016). In line with this, a substantial body of research has identified activity of the EBA to be associated with elevated electrophysiological (EEG) activity in occipito-temporal sites around 150-190 ms (N170) after stimulus onset in response to viewing body stimuli (Pourtois, Peelen, Spinelli, Seeck, & Vuilleumier, 2007; Thierry et al., 2006). The same body-sensitive N170 component is affected by body-structural distortion (e.g., Gliga & Dehaene-Lambertz, 2005) and in women at risk of body image disturbance (Groves et al., 2017). Furthermore, the N170 body-sensitivity has been found to be modulated by the gender of the body observed in both men (Hietanen & Nummenmaa, 2011) and women (Alho, Salminen, Sams, Hietanen, & Nummenmaa, 2015). Women with a history of EDs or BDDs have also showed a gender-sensitive response to other women's bodies over N170, while those without such a history do not show this response (Groves, et al., 2017). However, body-sensitive and gender-sensitive inversion effects were yet to be examined in those either 'at-risk' or clinically diagnosed with MD. Findings from our investigations, presented in Chapters 2, extend Groves et al.'s (2017) findings for gender-sensitive responses at N170 with a history of EDs or BDDs, where we found enhanced processing of female relative to male bodies at N170 was driven by High risk women observing more desirable body types. However, unlike Hietanen & Nummenmaa's findings for healthy men (2011), no comparable or reverse gender effects over N170 in High risk men, or indeed in any of the other groups. Taken together, this calls for further research which seeks to directly address the potential mechanisms underlying visual processing in MD populations.

Previous research has demonstrated the LPP reflects aesthetic evaluation processes (Amodio, Bartholow, & Ito, 2014; Cui, Cheng, Lin, Lin, & Mo, 2019; Roye, Höfel, & Jacobsen, 2008; for review see Jacobsen, 2013). Findings from our investigations, presented in Chapter 2, support the idea that there are aesthetic processing differences for bodies over the LPP, where we found more desirable bodies elicited larger LPP waves than less desirable bodies overall. At the same time, more detailed analyses for the different groups revealed that these differences were restricted to female participants, and also that among them, they differed as a function of risk group: low-risk women drove the desirability effects just mentioned, while high-risk women in fact showed gender-sensitivity in the reverse direction, where less desirable female bodies elicited heightened processing compared to less desirable male bodies. We surmise that this may be an indication of evaluating size differences in others' bodies as relevant to the self (Uusberg et al., 2018) - the 'fear of fatness' that characterises women with EDs.

Therefore, both N170 and LPP amplitudes could be considered potential biomarkers for body desirability and heightened body image concerns, at least in women. However, both the gender of the presented body stimulus and its shape and size need to be carefully considered in designing future studies on clinical and non-clinical populations.

Findings from Chapter 2 also show behavioural inversion effects (BIE) across our sample with upright bodies being identified faster and more accurately than inverted bodies, which indicates configural processing of upright bodies. We also found that male body stimuli elicited much larger behavioural BIEs than female body stimuli, this pattern might suggest greater objectification of female than male bodies (e.g., Bernard et al., 2018). However, this was not replicated in ERPs for male and female bodies, which argues against objectification accounts. We also found that risk groups were characterised by larger and gender-sensitive BIEs: behavioural BIEs were larger for male than female body stimuli in high-risk men and were statistically absent for female bodies in this group. Although BIEs appeared similar for male and female bodies in High risk women, they were statistically absent for male bodies in this group, suggesting that High risk participants only showed reliable behavioural BIEs for bodies of their own gender.

Overall, the presence of BIEs and the finding that such BIEs were not clearly smaller in those at risk does not support the hypothesis that those at risk have reduced configural processing of bodies (Beilharz et al., 2016; Duncum et al., 2016; Feusner, Moller, et al., 2010; Groves et al., 2020; Mundy & Sadusky, 2014; Urgesi et al., 2012; 2014), which should have led to reduced BIEs.

Furthermore, in Chapter 2 we also found that men with smaller BIEs in accuracy had higher levels of muscularity-oriented disordered eating psychopathology. Gender differences in BIEs showed contradictory correlations for RTs and accuracy, such that greater body image concern symptomology was both associated with larger gender differences in BIEs in RTs and with smaller gender differences in BIEs in accuracy. Men with higher scores on MDDI total, greater discrepancies between actual and ideal fat-free muscle mass, greater internalisation of body ideals and greater pressures to follow those ideals had larger gender effects in BIEs in RTs. Men with more appearance intolerance and greater internalisation of muscle ideals had smaller gender differences in BIEs in accuracy. Together with other findings, this suggests several things. One is that larger BIEs in RTs. especially for bodies of one's own gender, may be indicative of body image disturbance in men. Another is that the accuracy of body discrimination in body inversion tasks may be the more reasonable marker of MD symptomology in men because this measure behaved in line with expectations, such that reduced BIEs, suggestive of reduced configural processing, were associated with increased BIC symptomology in men. In either case, our findings suggest that atypical configural body representation is not only present in women with anorexia (Urgesi et al., 2014), with (subclinical) dysmorphic concern (Mundy & Sadusky, 2014) or with a history of eating and body dysmorphic disorders (Groves et al., 2020), but that it might extend to men at-risk of MD.

For women, we found that greater BIC symptomology was associated with larger BIEs in RTs and in accuracy, as well as with larger gender differences in BIEs, was not associated with N170 BIEs, but was associated with greater hemispheric differences in N170 BIEs. We found that women with larger BIEs in RTs had higher asceticism (EDI) and viewed their body more like an outside observer. Women with larger BIEs in accuracy also had lower self-esteem and more interpersonal insecurities, as well as less strong beliefs that others have control over their own appearance. BIC symptomology correlated with gender differences in BIEs in accuracy but not in RTs. Women with larger gender effects in BIEs in accuracy also had more bulimic symptoms. Therefore, it appears that larger BIEs and larger gender differences in BIEs (larger BIEs to male than female bodies) are associated with increased risk of body image disturbance. This contradicts what was hypothesised, but is in line with risk-group-based differences seen in behavioural and ERP data in that they do not support the hypothesis that those at risk have reduced configural processing of bodies (Beilharz et al., 2016; Duncum et al., 2016; Feusner, Moller, et al., 2010; Groves et al., 2020; Mundy & Sadusky, 2014; Urgesi et al., 2012; 2014), One potentially important set of correlations emerged from the hemispheric differences in N170 BIEs: women with more hemispheric imbalances (i.e., smaller BIEs in right hemispheres and larger BIEs in left hemispheres) also report more eating disorder symptoms and a greater tendency to view their own body from an external perspective.

These findings suggest that effects of body inversion and their relations with measures of body image disturbance may differ between men and women, which is opposite to what was originally hypothesised. It is also clear that the power of BIEs as markers of body image disturbance warrants further investigation, especially with gendered bodies and low- and high-risk populations. Here we appear to show more evidence that risk of body image disturbance is related to increased (rather than reduced) body inversion effects in brain and behaviour. A potentially important biomarker of at-risk populations also emerged: hemispheric imbalances in N170 effects of body inversion.

Findings from Chapter 2 also suggest that hemispheric imbalances in body inversion effects in High risk groups are consistent with reports of the left-lateralised structural abnormalities in body-selective cortical regions and body image distortions in women with eating disorders (Smeets & Kosslyn, 2001; Suchan et al., 2010, 2013). Our findings extend such observations of hemispheric asymmetries to women who have recovered from eating disorders as well as to an at-risk population of men. Together, this strongly suggest that, unlike other measures taken in the present study, hemispheric imbalances in N170 body inversion effects may be the most generalisable biomarker of body image disturbance risk.

With that in mind, we feel that this thesis makes three major contributions to the understanding of visual body processing in those at-risk of body image related disorders. These includes evidence of gender-sensitivity and gender-sensitive body inversion effects and behaviour in ERPs (N170 and LPP) in High risk women, with High risk men also showing some atypical body inversion effects. Thirdly, both High risk men and women were characterised by hemispheric imbalances in N170 body inversion effects, which could be considered a potential biomarker of persons at risk of body image disorders, which may precede the emergence of measurable behavioural effects.

**Evidence for the association between interoceptive sensibility and muscularity-oriented disordered eating in resistance training gym-goers**

Previous research has demonstrated that lower levels of interoceptive accuracy and interoceptive awareness contribute to body-image concerns (Badoud & Tsakiris, 2017). For instance, lower interoceptive sensibility has been associated with less positive body image, more negative body image, and greater body image disturbances (e.g., Brown et al., 2017; Cascino et al., 2019; Daubenmier, 2005; Jenkinson et al., 2018; Myers & Crowther, 2008; Todd, Aspell, Barron, & Swami, 2019a; Todd, Aspell, Barron, & Swami, 2019b), and can be observed in subclinical populations with disordered eating behaviour (Brown, Smith, & Craighead, 2010; Koch and Pollatos, 2014; Young et al., 2017). However, to our best knowledge, the association between interoceptive awareness and muscularity-oriented disordered eating was yet to be explored. Unlike previous research, which has associated lower interoceptive sensibility with increased eating disorder symptomology and greater body dissatisfaction (Ainley & Tsakiris, 2013; Brown et al., 2017; Cascino et al., 2019; but see Lutz et al., 2019), as well as our findings from Chapter 2, which showed left-hemispheric abnormalities in eating disordered women related to interoceptive deficits, our findings from Chapter 3 suggest that increased interoceptive sensibility systematically relates to increased muscle-oriented disordered eating behaviour in resistance training gym goers of both sexes. However, our findings from Chapter 3 do relate to previous research which found that bodybuilders have heightened interoceptive awareness compared to both individuals of other sports and non-bodybuilders (Blouin, & Goldfield, 1995; Babusa & Túry, 2012) and to a recent study showing evidence that women with anorexia nervosa have enhanced, rather than reduced, interoceptive signal processing (Lutz et al., 2019). Interestingly, one previous study has also shown that increased interoceptive awareness was associated with increased MD symptoms (Babusa & Túry, 2012). We have demonstrated in Chapter 3 that this relationship extends to resistance training gym-goers, and that it affects muscle-oriented eating behaviours (e.g., overregulation of protein consumption, with arbitrary rules relating to the amount and timing of protein consumption, where any deviation from causes marked distress). Further research into the mechanism behind the relationship between increased interoceptive sensibility and increased muscle-oriented disordered eating behaviour is warranted, as well as the extent to which supplement use and MD symptoms mediate this relationship. Future repetition studies are encouraged which examine the present mediation model across other objective measures (e.g., muscular effort weight estimation task; Murphy, Catmur, & Bird, 2018), alongside self-reported measures of interoceptive sensibility and muscle-oriented eating behaviour, allowing researchers to explore the proposed relationships with greater fidelity.

Therefore, based on our findings from Chapter 3, increased interoceptive awareness may be considered a potential risk factor for the development and maintenance muscle-oriented disordered eating and MD in resistance training gym-goers.

**Muscle dysmorphia symptomology, exercise using gym equipment, mood, and perceived social pressures in gym members.**

Previous research has highlighted those at-risk of MD are dependent on use of gym equipment for their regular exercise routine (Olivardia, 2001; Olivardia, Pope Jr, & Hudson, 2000; Pope Jr, Gruber, Choi, Olivardia, & Phillips, 1997). Our findings indicate that gym members at-risk of MD mood state was negatively impacted from being unable to access as much gym equipment as they usually would during the lockdown. The self-reported increase in depression and frustration towards being unable to exercise as normal in gym members at-risk of MD, may be arguably due to them having to make significant adjustments for exercising at home due to the forced sudden inaccessibility of gyms and their dependence on gym equipment. Additionally, previous research has found that during the COVID-19 pandemic-related lockdowns, there were pronounced exercise reductions in active individuals when compared to less active individuals (Hargreaves et al., 2021; Fearnbach et al., 2020; Castañeda-Babarro; Giustino et al., 2020). In line with this, findings from Chapter 4 further supported the reductions in active individuals in the UK, we found that reduction in time spent exercising during lockdown was significantly greater in gym members than non-gym members. With leisure centres, gyms (both indoor and outdoor) and other fitness facilities being forced to close, the COVID-19 pandemic-related lockdown presented a unique opportunity to study the relationship between muscle dysmorphia symptomology, exercise using gym equipment, mood, and perceived social pressures in gym-members. These findings were explained through non-gym members possessing pre-existing established exercise routine (either at home or in freely accessible outdoor spaces), whereas gym members may have had to make significant adjustments for exercising at home due to the forced sudden inaccessibility of gyms in the UK.

Also, in Chapter 4 we found that gym membership (without being able to access gyms) predicted greater self-reported depression and more self-reported frustration towards being unable to exercise as normal. These findings support previous studies demonstrating that mood deteriorates when exercise regimes are either interrupted (Mondin, et al., 1996; Peluso, & Andrad, 2005; Wittig, McConell, Costill, & Schurr, 1992; Szabo, Frenkl, Janek, Kalman, & Laszay, 1998), or completely withdrawn (Berlin, Kop, & Deuster, 2006), and suggest that gym closures may have contributed significantly towards the observed increase in mental health conditions during the lockdown. The self-reported increase in depression and frustration towards being unable to exercise as normal in gym members, may be arguably due to them having to make significant adjustments for exercising at home due to the forced sudden inaccessibility of gyms compared to non-gym members had pre-existing exercise routines (either at home or in freely accessible outdoor spaces). Such closures may have contributed significantly towards the observed increase in mental health conditions during the lockdown

Previous research on home-based exercise interventions has also indicated that access to home equipment is a contributing factor towards exercise adherence in general (Jakicic, Winters, Lang, & Wing, 1999; Taylor, Dodd, McBurney, & Graham, 2004). In line with this, we found that the self-reported reduction in exercise during the COVID-19 lockdown was greater in those with ≤ 1 piece of home equipment compared to those with ≥ 2 pieces of home equipment, which implies that having access to home exercise equipment is crucial for continuing engagement in exercise at home.

In Chapter 4 we also found that gym members reported significantly greater social media usage, as well as social media pressures to exercise and to ‘transform’ their body during the COVID-19 lockdown compared to non-gym members. These findings imply that during the COVID-19 lockdown gym members were not only using social media more, but also (and perhaps as a result) perceiving greater pressure to exercise and ‘transform’ their body compared to non-gym members. These findings therefore support previous studies which found gym members to be at greater risk for developing issues related to body image and mental health concerns in comparison to non-gym members (Prichard & Tiggemann, 2008; Stapleton, McIntyre, & Bannatyne, 2016). Therefore, it may be argued that gym members with MD symptoms may be at greater risk for developing enhanced body image concern, including MD symptoms, when there are restrictions to gym access (e.g., as seen during the COVID-19 lockdown). Together with our other findings, it may be suggested that access to home equipment mitigates this risk.

Altogether, the findings from Chapter 4 represent the first direct demonstration that gym members at-risk of MD experienced enhanced mood disturbance during the lockdown, these effects were enhanced for those with less access to compensatory home gym equipment and reduced perceptions of support from social media. The present study has also demonstrated that gym members have experienced disproportionate levels of mood disturbance, reduced exercise engagement, and perceived social pressures to exercise for appearance-related reasons particularly in comparison to non-gym members. These effects were elevated in those with less access to compensatory home gym equipment, and in those with a greater propensity to exercise excessively. Therefore, the policy of government to close gyms during the lockdown was not without detrimental consequences for gym members and members (and general exercisers) may even contributed to the increased poor mental health observed during the COVID-19 pandemic. Should future lockdowns be imposed the governments department of public health need to consider carefully how to handle similar pandemic situations in the future such circumstances in future.

**Utility of visuospatial body map tasks to identify increased risk of body image disturbance**

Previous research has demonstrated that AN patients have a persistent disturbed experience of their own bodies, caused by distorted body representations (Gadsby, 2017, Keizer, Smeets, Postma, van Elburg, & Dijkerman, 2014; Keizer et al., 2013; Spitoni et al., 2015). Specifically, improved feature-based processing has been previously found in both adolescent girls at risk of body image disturbance (Groves et al., 2020; Mundy & Sadusky, 2014) and in women with eating disorders (Urgesi et al., 2012). In line with this, our findings from Chapter 5 demonstrate that improved feature-based processing is present among women and men with more subclinical symptoms of body image disturbance for the visuospatial body map task, albeit in different measures of the task. In men, this improved feature-based processing was specific to same-sex bodies on a measure of body part localisation. In women, improved feature-based processing was found for both male and female bodies on a measure of body part selection. Enhanced feature-based encoding for bodies of both genders differs from Groves, et al. (2017) and our findings from Chapter 2. This suggests that different tasks tap into body-structural encoding mechanisms in slightly different ways. The body map task used speed and accuracy of selecting between different sized body parts to identify the one previously presented in the context of a full body. Feature-based processing captured in this way may be less sensitive to body gender.

Furthermore, our findings from Chapter 5 show that the overestimation of body size may be limited to AN populations (Daurat-Hmeljiak et al., 1978; Spitoni et al., 2015), because in our sample of healthy and subclinical populations neither women nor men with increased body image concerns were found to over-estimate body width. Intriguingly, this suggests that enhanced feature-based processing as a risk factor of body image disturbance may precede the emergence of reduced configural processing, which appears to be restricted to clinical populations and those recovered from body image disorders (Beilharz et al., 2016; Duncum et al., 2016; Feusner, Moller, et al., 2010; Groves et al., 2020; Mundy & Sadusky, 2014; Urgesi et al., 2012; 2014).

Overall, our findings from Chapter 5 support our findings from Chapter 2, which suggested that atypical configural body representation is not only present in women with anorexia (Urgesi et al., 2014), with (subclinical) dysmorphic concern (Mundy & Sadusky, 2014) or with a history of eating and body dysmorphic disorders (Groves et al., 2020), but that it may extend to men at-risk of MD. However, it must also be noted that there were differences between the male and female sample in both chapters. Possible explanations for findings in Chapter 5 are that perceptions of body size accuracy in men may exhibit greater variability than women (Cafri & Thompson, 2004). Women desire thinner bodies (Oehlhof, Musher-Eizenman, Neufeld, & Hauser, 2009), men desire high degrees of muscularity and low degrees of body fat (Leit et al., 2001; Pope Jr et al., 1999). Therefore, it was concluded from Chapter 5 that the body map task is a quick-to-administer and useful tool for capturing individual differences in body structural encoding in both men and women, but that future versions targeting men should also focus on measuring misperceptions in relation to body composition rather than only body size.

# Limitations

The work presented within this thesis is not without limitations. For instance, Chapters 2 to 6 explored non-clinical samples. Recruiting and studying visual body perception in men who had experienced disorders characterised by body image disorders (e.g., MD) would have been preferable, but was not possible given the time limits of this thesis and the difficulty in recruiting persons with an MD history. Whilst non-clinical sample do not invalidate or diminish the presented findings, perhaps one of the most obvious limitations is that it might not be possible to generalise the interpretation of our findings beyond populations 'at-risk' of ED/BDD/MD symptomatology. In addition, as mentioned in the introduction, MD can often be comorbid with other disorders, such as eating disorders, depression, or obsessive-compulsive disorder, and therefore is often misdiagnosed and undetected (Murray et al., 2010; Pope et al., 2005). It is therefore unknown if variables in Chapter 2 to 6 function similarly among those with clinical levels of body image and eating disturbances, and how they may be affected by clinical comorbidities. Moreover, given that in Chapter 2 we argue for objectification and social comparison processes as a possible explanation for gender-sensitive ERP effects, it is possible that these might present as enhanced to male bodies if a clinical male population with ED/MD were to be tested. Therefore, future research is warranted across body image related disorder populations, especially within clinically diagnosed MD samples, to establish the extent body perception, cognition and emotion relate to individuals with a clinical MD diagnosis. Another limitation includes the use of self-report measures across Chapters 2 to 6. Participants may have been impacted by social desirability bias, underreporting symptoms in order to present themselves favourably (Tooze et al., 2004). With that in mind, questionnaire measures of symptomatology are often criticised for not capturing body image concern (e.g., Dakanalis & Riva, 2013) or objectification (e.g., Daniel & Bridges, 2010) adequately in men, as many of these measures have scarcely been researched in this population. We also noticed that questionnaires might not specifically assess what we would like them to. As a result, it is possible that the effects we observed in ERPs and behaviour are associated with constructs that were not measured. For example, with the MDDI, body checking is acknowledged as a common behavioural symptom of BDD and MD, but no MDDI subscales related to this. Therefore, we felt that these MD subscales did not quite tap into body image disturbance as we wanted to do because, for example, camouflaging and checking behaviours were not assessed across Chapters 2 to 4. As such, this may have supressed the correlations between MDDI scores, and the effects observed in Chapters 2 and may have found more pronounced effects across the other Chapters where effects were observed with MDDI scores. Progressing from this, across our male sample in Chapter 5 we chose to include and administer the BICI which does measure camouflaging and checking behaviours. Moreover, self-objectification is completely omitted from MDDI and might not be adequately reflected in all populations by objectified body consciousness scale, especially as the objectified body consciousness scale was initially developed for, and tested exclusively with, young and middle-aged women (e.g., Chen, & Russo, 2010). Overall, we feel that the interpretations of effects are limited because each questionnaire used does not fully capture MD symptomatology and/or reflect diagnostic criteria. Thus, it may be beneficial for future studies to seek professional, clinical assessment of participants' levels of MD as it is likely that symptomatology does not present as precisely, and distinctly as self-reported questionnaires would suggest. Interestingly, the potentially limited utility of self-report measures in assessing body image disturbance and related MD symptoms in men highlights the need for research on objective symptoms markers, which was one of the aims of the thesis.

Furthermore, in Chapters 2 to 6 only legal APED usage, therefore generalisability of the findings in Chapters 2 to 6 considering illegal APED use are unknown. Since the use of illegal APEDs is illegal, we expected that any illegal APED use would have been severely self-underreported in our samples across Chapter 2 to 6 (Harvey, Parrish, van Teijlingen, & Trenoweth, 2021). Other empirical studies have taken urine samples to accurately measure illegal APED use across their participant sample (Sader, Griffiths, McCredie, Handelsman, & Celermajer, 2001). This is something future studies could consider.

## Clinical implications and future directions

As previously mentioned, the behavioural and electrophysiological correlates of visual processing in populations at risk of ED, BDD and MD differ. This has direct clinical implications and inspires several other questions, including when and how these alterations to visual body processing develop, whether they are reliably evident at the individual level and correspond to conscious visual percepts (e.g., distorted mirror image), whether these differences are more pronounced in those diagnosed with ED/BDD/MD, and how they are affected in recovery from ED/BDD/MD. The discussion of results presented throughout this thesis go some way in trying to address such questions but ultimately, future research is crucial as it will be the key to understanding the full implications of the findings we outline here.

The most obvious line of future research perhaps, is to investigate these effects in clinical samples. We found both high risk men and women were characterised by hemispheric imbalances in N170 body inversion effects, which appears to support findings of similar asymmetries in the underlying cortical structures shown in (female) clinical patients. In addition to stronger left-than-right configural encoding, we also found more evidence that global encoding (at least of bodies) is much more nuanced than existing research suggests, as it was only diminished for some stimuli under some circumstances but was in fact heightened for other stimuli and other circumstances in both men and women at risk. Men at risk of MD, specifically, may be characterised larger behavioural (RTs) and N170 BIEs to male than female bodies. Women at risk, however, may be best characterised by mandatory gender-sensitive body encoding (larger N170 and LPP waveforms to female than male bodies) including under conditions when body-structural encoding is not explicitly required (passive viewing). Similarly, we found no evidence of diminished configural encoding in those with more body image concerns in our body map task.

Assessing clinical populations of men and women would further document the potential of these ERP effects as biomarkers of ED/BDD/MD symptomatology. An advantage of this would be that ERP biomarkers are substantially lower cost compared to structural MRI, which means that they could be used at larger scales for diagnosis and to chart recovery during treatment. Moreover, investigations should be conducted in those with a clinical diagnosis in order to ascertain whether the effects observed in this thesis are potential biomarkers limited to MD related body image disturbance more generally, or extend to persons with clinical levels of MD. However, to our knowledge, no study to date has investigated the temporal dynamics of visual body processing directly in MD with clinical diagnosis.

Neurostimulation techniques such as repetitive transcranial magnetic stimulation (rTMS) and transcranial direct-current stimulation (tDCS) have been found to increase functional connectivity (e.g. Kunze, Hunold, Haueisen, Jirsa, & Spiegler, 2016; Okabe et al., 2003), reduce disorder-specific symptoms (e.g. Kalu, Sexton, Loo, & Ebmeier, 2012; Sokhadze, El-Baz, Sears, Opris, & Casanova, 2014) and modulate ERPs in such a way that implies more efficient processing (e.g. Sokhadze et al., 2014) in AN populations (e.g., Bainbridge, & Brown, 2014; Jaššová, Albrecht, Papežová, & Anders, 2018; Mattavelli et al., 2019). Future research might aspire to addressing the possibilities of using neuromodulation in a clinical setting to establish more efficacious treatment protocols of body image disturbance in MD and disordered eating towards muscle-oriented foods.

The final line of future research proposed as a result of the investigations presented in this thesis, refers to utilisation of body ownership illusions and virtual reality (VR) techniques. VR can have a key role in the process of updating and improving the experience of the body, which have been recently shown to be successful for reducing body image distortions in anorexia nervosa (Clus, Larsen, Lemey, & Berrouiguet, 2018; for reviews see Magrini et al., 2022; Turbyne et al., 2021). There is great potential to adapt existing body ownership illusions and VR techniques to those at-risk or clinically diagnosed with MD and/or muscle-oriented disordered eating, ideally before those at risk develop clinical MD or to aid in the treatment of those already diagnosed. The recent interest in the study of multisensory bodily illusions, among which the rubber hand illusion is the main paradigm, may further improve the clinical potential of VR. In this illusion (Botvinick, & Cohen, 1998), feelings of ownership over a false hand are induced by synchronized stimulation of the real hand (by touch) and of the false hand (by sight). Many of these studies have been conducted using VR, allowing the manipulation of the perspective (first person, third person, and whole body) from which the body itself is observed in a way that would not be possible with other procedures (Petkova, & Ehrsson, 2008; Gutiérrez-Maldonado, Wiederhold, & Riva, 2016). Findings from such studies have revealed that the modulation of these illusions can also produce perceptual changes to the shape and size of the actual body, for example the illusory elongation of an arm (Preston, & Newport, 2012; Kilteni, Normand, Sanchez-Vives, & Slater, 2012) and illusory expansion of the stomach (Normand, Giannopoulos, Spanlang, & Slater, 2011). In line with recent findings for body image restoration in AN population using VR, similar VR based body distortion interventions specific to MD and muscle-oriented disordered eating behaviour are encouraged, as such an intervention may contribute reducing body image distortions and in MD populations. Such an invention may include displaying to the participants their own body from at 3rd person perspective in VR, which has been found as an effective approach for reducing body dissatisfaction and a more positive evaluation of body shape (Neyret et al 2020).

# Conclusion of thesis

This thesis aimed to investigate investigating perceptual (and some cognitive) contributions to body image disturbance in men and other populations at-risk by assessing the relationship between how the observer feels about their own body (body image) and body perception. We found some evidence to suggest a configural processing disruption of body stimuli in high-risk groups, suggesting atypical configural body representation is not only present in women at-risk of body image-related disorders, but might extend to men at-risk of MD. Gender-sensitive body processing was observed in women only. We also found during the COVID-19 pandemic that MD symptoms in gym members at-risk of MD positively associated with increased mood disturbance. Additionally, we found in an online visuospatial body map task that performance was associated with increased body image disturbance in women, highlighting implications for understanding how configural body tasks can be used to assess body image concerns in the general population. Future research is encouraged which intends to directly address the potential mechanisms underlying body processing difference within populations at-risk of MD, which could potentially provide further insight into body processing across MD populations.

Thus, the conclusion of this thesis is that processes indicative of body perception, in both brain and behaviour, present atypically in women at-risk of EDs/BDD, and differ to those in men at-risk of MD. Importantly, body-structural perception measures appear a suitable approach to delineating individuals at-risk of MD.

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