An investigation into the importance of off-horse exercise on riding position of horse riders

J. A. A. Prentice

A thesis submitted for the degree of Doctor of Philosophy in APPLIED BIOLOGY

School of Sport, Equine and Animal Sciences, Writtle College

University of Essex

September 2016

Abstract

In equestrian science, anecdotal evidence suggests that certain fitness parameters are beneficial for riding position. Studies have investigated the demands of riding; however, there is no objective data linking the general fitness of riders to its effects on riding position. This research set out to investigate the perceived importance of off-horse exercise on riding position, the impact that certain fitness parameters have and the effectiveness of a specifically tailored exercise programme. Nearly 90% of respondents stated they believed off-horse exercise to impact on their riding position, with dressage, leisure and older riders to be most likely to participate.

The average fitness of riders including aerobic capacity, core stability, balance, flexibility and posture was then researched regarding the effect these might have on riding position. In a cross sectional study the relationship with riding position and pressure distribution, looking at the laterality of the seat, were explored. With the exception of cardiovascular fitness these were then tested for transferability of skill in an intervention trial. A mechanical horse and video analysis were used for analysis and the TekScan pressure mat recorded pressure distribution. Aerobic capacity was found to have no impact on riding position in this study and hip flexibility was assumed to have the greatest impact on riding position. After the intervention, the range of motion of the angles was decreased suggesting a more stable and quiet seat due to increased core stability. In line with other research asymmetries in the rider were found in pressure distribution, which were significantly decreased post intervention (trot and canter). No improvements in medio-lateral symmetry were found. Transferability of skill in riding position can be explained with the high similarity of standing posture and riding position. Overall horse rider specific training regimes can be recommended for improvement of riding position, but combination with riding instruction is suggested.

Table of Contents

List of Tables

List of Figures

List of Plates

List of Appendices

Acknowledgements

I would like to take this opportunity to say a few thank you’s to some great people for making this thesis happen: First of all to all the subjects that have taken part in the several studies. Without you this thesis would have been void. Dr. Isobel Gowers for her support and guidance. It has been a pleasure working together. My horse Rishona in collaboration with my riding instructor Robin Gill for helping me make sense of some of the results when numbers got complicated. The staff at Writtle College, that have helped move equipment and facilitated my research in a technical way. My parents without whom I would not have had the audacity to even embark on this journey. My parents-in-law for supporting my logistically throughout some difficult study times. Steven my wonderful husband for supporting me and being the most amazing editor one could have. And all the fantastic people I am privileged to call my friends for having my back in prayer and being so very encouraging. I could not have done this without any of you and I am very grateful for your support.

Chapter 1

Introduction

Equestrian sport is widely participated in the United Kingdom. The National Equestrian Survey by the British Equestrian Trading Association (BETA) in 2011 found that 4.3 million people had ridden during the last year; this is equivalent to 7% of the total population (Office for National Statistics, 2009). Forty-nine percent of these people participated regularly in some kind of equestrian activity.

The BETA National Equestrian Survey (2006) estimated the annual contribution of the equine industry excluding racing to the GDP at £4bn or just over 0.3% (Guardian.co.uk, 2010). More than half (£2.6bn) of this money is spent generally on horses and riding, with paid riding lessons accounting for £372million.

Few studies have been carried out to investigate the physiological demands of riding (Westerling, 1983; Devienne and Cuezennec, 2000; Roberts, 2009) or the impact of the rider on the horse (Clayton *et al.*, 1999; Oldruitenborgh-Oosterbaan *et al.*, 1995). There is a lot of anecdotal evidence on what the ideal riding position should be, but little scientific studies have been undertaken (Schils *et al.*, 1993; Lovett *et al.*, 2004; Terada *et al.*, 2004). Recent research has suggested that core stability was beneficial to athletic performance (Kibler *et al.*, 2006; Mills *et al.*, 2005; Akuthota and Nadler, 2004; Bliss and Teeple, 2005) and this can be acquired through Pilates training amongst other training regimes (Sekendiz *et al.*, 2007; Johnson *et al.*, 2007). Conversely, Asseman *et al.* (2004) found that skills are not transferable between activities. Most other sports use conditioning programmes that do not entail participating in the actual sport for example strength training or cardiovascular conditioning. This conditioning is expected to have a beneficial impact on the performance of the given athlete (Reilly, 2006). It is therefore interesting for the equestrian community, who generally only train on the horse, to know if there are other conditioning programmes that would have a beneficial impact on riding performance.

This study was set out to gather the views of the equestrian population on the importance of off-horse exercise on riding position and gain a deeper understanding of riding position; in particular the relative angles between the head, torso, thigh and calf and the deviation of the riders body from the vertical as well as the impact of general fitness on riding position. As a part of this investigation a rider-specific exercise programme was also tested on its effectiveness of improving riding position.

Chapter 2

Literature review

2.1 Systematic review

To establish a basis of research that has been carried out in equestrian science a systematic review was carried out. The following databases were used: PubMed, Google Scholar and ScienceDirect. A search was carried out with the main keyword “horse-riding” followed by each of the following: fitness, biomechanics, kinematics, EMG, skill, flexibility, position and Pilates. All original research, peer reviewed articles were included with conference proceedings, abstracts, theses and non-peer reviewed articles being excluded. The remaining articles were then checked and everything that did not focus on the horse-rider was excluded, which resulted in a selection of eleven articles. These articles are summarised in Table 2.1 below as well as discussed in further detail throughout this literature review.

Table 2.1: Main results of research found through a systematic review.

Reference	Discipline	Participants	Main results
Physiological references			
Westerling (1983)	D/SJ	n=13 female (3 elite)	Riders use at lest 60% of their maximal aerobic power in trot and canter. Two out of three elite riders show lower oxygen uptakes than the rest. HR and oxygen uptake were similar between ergometer tests and actual horse riding.
Gutierrez Rincon *et al.* (1992)	SJ	n=3 sex unknown	Riders use more than 90% of their HR_{max} during show jumping with lactate levels of 4-9mmol/l.
Devienne and Guzennec (2000)	D/SJ	n=5 (3 female, 2 male)	Oxygen uptake was found to be greater in Show jumping than in dressage with the 75% of VO^2max being reached during Show jumping.
Meyers (2006)	-	n=15 female equitation; n=10 control	Equitation training (walk, trot and canter for 14 weeks, 5x per week) found significant improvements in muscle power, but not cardiorespiratory response.
Roberts *et al.* (2010)	E	n=16 female	A progressive increase in oxygen uptake (VO^2), HR and blood lactate was found between the phases of the competition.

			Mean heart rates for Dressage, Show jumping and Cross-country phases were 157 ± 15bpm, 180 ± 11bpm and 184 ±11bpm respectively.
Biomechanical references			
Lovett *et al.* (2004)	D	n=5 female	The riders' trunk angle was found to be in front of the vertical. Trunk Range of movement was 5.9°, 4.1° and 4.7° for walk, trot and canter respectively with lower leg RoM's being 7.3°, 2.9° and 3.9°.
Lagarde *et al.* (2005)	D	n=1 expert, n=1 amateur; sex unknown	The expert rider absorbed more movement through his ankle joint and showed better temporal regularity of the oscillations of the horse's body, resulting in a stronger phase synchronisation. Whereas the novice showed departures from phase synchrony and a tenser trunk.
Bystroem *et al.* (2009)	D	n=3 male, n=4 female	When the horse decelerates the rider hollows his lumbar spine, flexes his leg joints and extends his feet forwards. At propulsion, the lumbar spine is straightened, the leg extended and the feet and head are moved backwards.
Symes and Ellis (2009)	-	n=17 female	All riders displayed left axial rotation and greater ROM of the right shoulder in all gaits but right canter. Leg length inequality was also found in all riders with the right stirrup being shorter.
Kang *et al.* (2010)	-	n=3 riders, n=6 beginners	Trunk angulation was found to be an indicator of rider skill with the beginners showing a flexed forwards position. Beginners also showed plantar flexion even after a 24-week training programme as opposed to dorsiflexion of the experienced riders.
Peham *et al.* (2010)	-	n=1 experienced rider; n=10 horses	Riding position was found to be most stable in the two-point seat followed by rising trot and sitting trot. Sitting trot showed the highest load on the horses back followed by rising trot and the two-point seat.
Muenz *et al.* (2014)	D	n=10 professional (2 male, 8 female); n=10 amateur (1 male, 9 female)	In all gaits, the professional riders kept their pelvis closer to the mid position whereas the amateurs showed a more posterior tilt of the pelvis which was also towards the right.

Disciplines: D=dressage, SJ= show jumping, E=Eventing; Dressage is considered any form of horse riding that does not involve any jumping but is not necessarily linked to actual dressage movements.

2.2 The disciplines

In horse riding three Olympic disciplines are recognised: dressage, show jumping and eventing. Each of these disciplines requires a slightly different skill set from the rider, and the physiological demands placed on the horse and rider differ (Jeffcott *et al.*, 2009). The three disciplines are the most common in the UK along with recreational riding though a number of other disciplines are recognised within the British Equestrian Federation, the umbrella organisation of all governing bodies of equestrian sport in the UK (BEF, 2014).

Show jumping

In show jumping the horse and rider combination is required to overcome a parcour of obstacles together. Great strength of the horse's hindquarters is pivotal to push up from the ground to jump over and clear the jump. Show jumping is generally not started before the rider has developed a sense of balance on the horse to minimise the risk of injury to both horse and rider. Being able to maintain control over the horse through communication is also crucial (Deutsche Reiterliche Vereinigung, 1996). Since Captain Frederico Caprilli developed the forward seat the rider is now able to obtain a position over the jump that most aids the horse in overcoming the obstacle (Santini, 1967). Getting out of the saddle, thus relieving pressure on the horse's back, allows for the horse's freedom of movement and encourages the bascule, which is the rounding of the horse's back over the jump (Powers and Harrison, 2002). The light seat is characterised by a forward tilt of the upper body and raising the buttocks out of the saddle along with greater muscular tension (Kang *et al.*, 2010). This tension is necessary to compensate for the compromise in stability and facilitates the rider to better adjust to the changing centre of gravity and tempo of the horse (von Dietze, 2003). The rider's biomechanics, such as joint angles and trunk positioning, thus where his centre of gravity is located above the horse, all impact on the horse's balance and can ultimately facilitate or hinder ideal performance (Clayton, 1989).

Eventing

Eventing comprises of three phases of competition, which are show jumping, dressage and cross-country phase. With the level of competition physiological and technical demands gradually increase (BE, 2014). Because of the increased demands on horse and rider the higher-level competitions are usually held on three days with the lower levels of competition commonly taking place on one day (Deutsche Reiterliche Vereinigung, 2001). The top level cross country course is designed to comprise approximately 45 fences on a course that is between six and seven miles in distance. The available time to complete is calculated to a going rate of 570mpm, which is generally about 12 minutes (Mitsubishi Motors Badminton Horse Trials, 2013). High speed and a long time spent in the light seat, will lead to fatigue earlier than when using the dressage seat. Where the dressage seat is more stable, because the building blocks (pelvis, trunk and head) are arranged vertically above each other, the light seat in which the trunk is anteriorly displaced, requires greater tension (van Dietze, 2003). It is commonly accepted that oxygen consumption (31.2ml/kg/min) and heart rate (184bpm) in eventing are greater than in dressage (20.4 ml/kg/min; 157bpm), where a more stable seat is used and less energy required to stay balanced, or show jumping (28.4ml/kg/min; 180bpm), where the time spent in the light seat is much shorter (Roberts *et al.*, 2010). To prevent elimination and more importantly injury both horse and rider must possess good cardiovascular and musculoskeletal fitness (Jones and Knapik, 1999).

Dressage

Dressage is commonly described as the ballet of horse riding. Horse and rider are required to perform a set sequence of movements in an enclosed area. These are subjectively judged on their technical and aesthetic correctness (Deutsche Reiterliche Vereinigung, 2001). The most advanced level of competition is Grand Prix where the average test lasts approximately 7 ½ minutes as opposed to the 4 minutes of a preliminary test (BD, 2014). Technical difficulty and physiological demands progress through the levels with the movements at the highest level requiring the horse to collect, which mean transferring the majority of its weight onto its haunches and elevating through the shoulder (Plinzner, 2002). A rider that is less of a hindrance for the horse in this makes this task much easier and facilitates more spectacular gaits (Strick, 2002). On the basis of being as little disturbance to the horse as possible the classical seat has been developed primarily under the influence of Xenophon (Widdra, 2007). The following review of riding position focuses mainly on the dressage seat due to the nature of the study.

2.3 The Gaits

The riding horse has three basic paces: walk, trot and canter (Deutsche Reiterliche Vereinigung, 1996). All these have different tempi, depending on the degree of collection and the stride length of the horse. The spatial and temporal symmetry is known as tact and is specially emphasised in all three basic gaits (Strick, 2002).

Walk

The walk is an asymmetrical four beat rhythm with no suspension, which means that at least one leg touches the ground at all times. The tempi are collected walk, regular walk and free walk. The medium walk is starting to be introduced at Medium level dressage and the free walk is one of the most difficult tasks in top-level dressage. The lack of suspension phase results in lower ground reaction forces, meaning that the rider needs to absorb less energy and is less influenced by the horse (Clayton, 2004) and in turn was found to have the greatest influence on the gait of the horse (Bystroem *et al.*, 2010).

Trot

The trot is a two beat, symmetrical gait with a moment of suspension. The tempi are working trot, medium trot, collected trot and extended trot (Deutsche Reiterliche Vereinigung, 1996). The diagonal limb pairs ideally move synchronously and after each diagonal support phase a suspension phase follows. The diagonal pairs are left fore (LF) and right hind (RH) in the left diagonal pair and right fore (RF) and left hind (LH) in the right diagonal pair (Clayton, 2004). Dissociation of the diagonal pair is possible and known as diagonal advanced placement (DAP) which can be either positive or negative (Clayton, 1994). Holmström *et al.* (1994) found that in Elite dressage horses positive DAP is desirable, in which the landing of the diagonal hind limb antedates the landing of the forelimb. The limb-support sequence in trot ignoring DAP is shown in Figure 2.1. A correct trot is the most symmetric gait in the horse and is primarily chosen for lameness detection, as it allows for identification of asymmetry in movement patterns. Greater vertical displacement through the suspension phase leads to greater vertical ground reaction forces (GRF's) in trot compared to the walk which means that the rider will have to absorb more energy through his seat in order to be able to sit quietly and balanced (Clayton, 2004).

Since trot is a symmetrical gait the forces in left and right limbs are similar, with the front limbs having higher amplitude than the hind limbs, reflecting the location of the Centre of Gravity_(CoG) (Merkens *et al.*, 1993). The vertical force rises from ground contact, peaking at mid-stance, which is when the body moves over the leg, and then falling again towards lift-off. Propulsion (acceleration) and breaking (deceleration) are concerned with the forward motion and result in positive and negative longitudinal GRF's throughout the stride cycle. In trot, the early stance is characterised by deceleration and late stance by propulsion with the direction of the longitudinal GRF changing around mid-stance (Clayton, 2004).

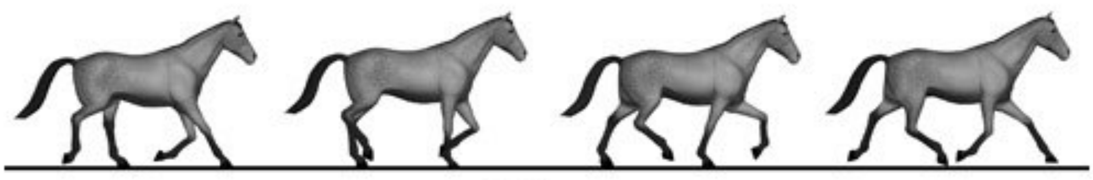

Figure 2.1: The first half of the limb-support phases in trot; right diagonal pair and suspension phase. The same follows for the left diagonal pair and the second suspension phase.

(*Source:* S.G.Equestrian, 2010)

Canter

The canter is a three beat, asymmetrical gait with a moment of suspension. The tempi are working canter, medium canter, collected canter and extended canter. Depending on which lateral limb pair moves further forward the canter is known as either ~~in~~ left or right lead (Deutsche Reiterliche Vereinigung, 1996). There is one limb pair and two separate limbs used in sequences. The most forward front limb is the leading front limb (LF), the diagonal pair is made up of the leading hind limb (LH) and trailing front limb (TF) and the last one is the trailing hind limb (TH). The limb-support sequences are shown in Figure 2.2 below.

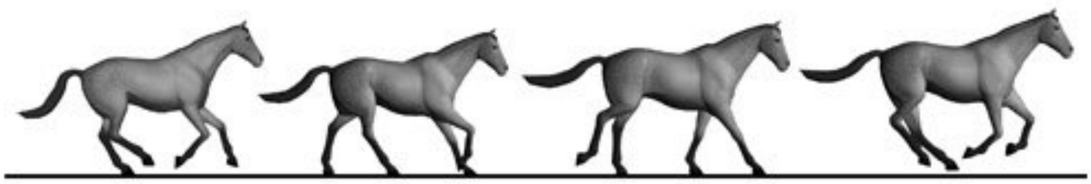

Figure 2.2: The limb-support phases in a right lead canter. (*Source:* S.G.Equestrian, 2010)

The ranking of intensity of vertical GRF is LF, LH, TH and then TF with the load on the LF being 25% more than that of the TF. Longitudinal GRF patterns are asymmetric for all four limbs. The LF decelerates the body with slight aid by the TF, which is also used for propulsion. The TH propels with contribution of the LH, which is also used for deceleration. The biggest force, however, is exerted on the rider from the LF on landing because of the deceleration action (Merkens *et al*., 1991).

Mechanical horse

The mechanical horse has a range of gaits that have the same biomechanical gait patterns that real horses have (Racewood Ltd., 2016). These are constant, whereas there is variation in each stride in real horses (Terada *et al.*, 2004). An advantage is that it is safe to use because no unexpected movements will occur. A disadvantage would be that the large variety of different moving horses are not accounted for. The mechanical horse will also not tire and can therefore be used for a much larger number of subjects at a time. The static set up of the mechanical horse also implies that the longitudinal forces acting upon the rider are much reduced (Clayton, 2004). Despite being used commonly in research studies there has been little research carried out on the differences and similarities of the mechanical horse and real horses. No peer reviewed data was found on the biomechanical differences; however, previous unpublished data by Marloes Vogel at Writtle College suggested no significant difference in angles in riding position between the mechanical horse and real horses. Physiological differences were investigated by Ille *et al.* (2015) who found a lower sympathetic response in riders caused by the simulator than real horses. This study looked at salivary cortisol, heart rate and heart rate variability when completing a show jumping course on the simulator trainer and on a real horse in young adults. The lower heart rate response found on the mechanical horse suggests less physical effort, whereas the higher cortisol suggests a higher stress response caused by the novel situation of simulator training. Kim *et al.* (2015) recorded greater enjoyment from riding a real horse as opposed to the simulator; however, found no significant differences between task difficulty, oxygen uptake or metabolic equivalents. These studies looked at using the riding simulator as a safe alternative to horse riding and did not validate the use of the simulator for research purposes. Walker *et al.* (2016) recognise the differences between the simulator and real horses in horse racing and name the main benefits of the mechanical horse to be “reduced risk of injury to the horse or rider falls and greater scope to physically correct technique while improving muscle and movement-specific fitness”. Their research found that the horses’ movement patterns showed greater dorso-ventral, medio-lateral and roll amplitude but smaller cranio-caudal displacement amplitude suggesting that the simulators may benefit from adapting the programming to show greater alignment with the gait of a real horse. To date it cannot be said to what degree the mechanical horse simulates the gait of a real horse and what difference this makes for rider position.

2.4 Riding Position

The above-mentioned disciplines all require the equestrian to adapt a medial position that is based on the classical seat as first explained by Xenophon (Widdra, 2007). The medial seat he described is different to that of sitting on a chair but rather like standing with slightly abducted hips, the knees angled and an upright pelvis (0° pelvic tilt). To allow for the ideal working environment for the horse and rider dyad the riders needs to maintain a balanced seat lining up his and the horse’s centre of gravity (Dietze, 2003). This is the position in which the rider is believed to allow the horse freedom of movement by least disturbing its balance (Clayton, 2004).

Between the disciplines the ideal position is variable, but in all three the rider depends on coordination, core strength, balance and alignment with the horse’s timing to remain in balance with the horse’s movement (Steiner, 2003). The ultimate goal is to be in harmony with the horse’s gaits allowing for the invisibility of aids (Deutsche Reiterliche Vereinigung, 1996). In this thesis, the focus will be on the classical seat that is adapted for general schooling or dressage.

It is commonly taught that three straight lines should be visible in the rider. One runs from heel through hip and shoulder to the ear, indicating upright position above pelvis and sacrum (Schamberger, 2002). The second one runs from the bit through the rein and wrist to the elbow, allowing for a soft and elastic contact. The last should be a vertical to the floor running through the horse's spine straight up the rider's vertebral column and middle of the head, i.e. the medial plane through rider and horse (Figure 2.3) (Deutsche Reiterliche Vereinigung, 1996). It must be noted that these are based on a static image of the horse rider and that during movement this static position will be constantly adapted to the kinematic phases of the gait to maintain posture and balance (Terada *et al.*, 2004).

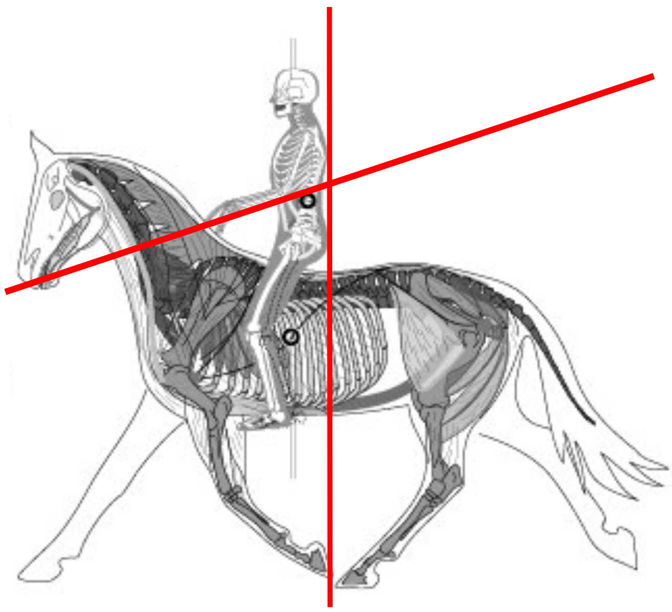

Figure 2.3: The aligned classical seat showing two of the three desired straight lines from a lateral view along with the horse's and rider's centre of mass. (*Source:* adapted from Nicholson, 2006)

Schils *et al.* (1993) compared relative angles between the torso and upper leg (hip), and the upper and lower leg (knee) and absolute angles between the horizontal and trunk, thigh and lower leg. The hip angle was found to be more extended in all three gaits in the advanced than the novice riders. This confirmed the anecdotal assumption that the advanced rider sits closer to the vertical, whereas the novice tends to lean their trunks forward. The reason for this could be that the advanced rider was found to absorb more movement through his ankle joint and was able to adapt better to the oscillations of the horse's body. The novice rider showed greater departures from phase synchrony and a tenser trunk (Lagarde *et al.*, 2005). This is supported by the findings of Kang *et al.* (2010) who also found greater ankle dorsiflexion in the experienced rider as opposed to the ankle plantar flexion and the flexed forward trunk position of the beginner. It should be noted that 61% of the subjects participating in Schils *et al*.'s (1993) study were classified as English riders, whereas the remaining 39% were practicing the Western style. This is important, because the Western and English riding styles make use of a different type of seat and were developed for different purposes. Generally, it can be said that the English rider aims for the vertical straight line that has been previously discussed; whereas the Western rider has a more casual approach and would often extend the trunk posteriorly behind the vertical with more extended knee angles and resulting in an anterior deviation of the lower leg to master the tasks such as roping or barrel racing. Bystroem *et al.* (2009) found that the hollowing of the lumbar spine along with flexion of the legs and anterior displacement of the feet was coupled with the deceleration of the horse, whilst the lumbar spine was straightened, the leg extended and the foot and head moved backwards during propulsion. This means that the increased GRF caused by deceleration caused the rider to lose stability temporarily.

When the spine and hip are in neutral position and the weight is equally distributed on both sides of the saddle the classical seat is achieved. Also known as aligned seat, the rider is in a relaxed and balanced position which is constituted of the spiral alignment of *latissimus dorsi* and the *medial gluteal* muscles (Nicholson, 2006). This seat allows for the rider to optimally cushion and absorb the horse’s movement from beneath (Dietze, 2003). The pelvis is accepted as the basis of a supple seat due to its anatomical characteristics. Every movement of the pelvis has a direct effect on the hip joint and lumbar spine and thus flexibility is necessary to allow the rider to join the horse’s rhythm (Dietze, 2003). Balance, being a part of the scales of training, can be assumed to be essential to achieving the ultimate goal of straightness (Dietze, 2003). The fine balancing movements of the body in the medial position create the optical illusion of a static seat (Ritter, 2013). The base on which the upper body is balanced is the triangular seating area of the pelvis and the load of the body is evenly distributed on both sides of the buttocks and the inner thigh musculature (Deutsche Reiterliche Vereinigung, 1996). The legs aid in stabilising the body and hang from the pelvis like pendulums with the thighs turned in slightly and the knees resting against the saddle (Dietze, 2003). A low knee positing is desirable as it facilitates the correct position of the lower leg and a deeper seat in the saddle. The correct stirrup length is determined by the knee angle which will place the foot under the centre of gravity of the rider. The inside of the lower leg should be placed slightly behind the girth and be in constant slight contact with the horse’s side (Schnitzer, 2013). The foot should rest in the stirrups slightly behind the metatarsal bones and parallel to the horse’s body, making the heel the lowest part of the rider's body (Wiemer, 2013). The upper body should be held upright but unstrained in the middle of the saddle with the spine in the natural position of the double S curvature. A round or hollow back make the seat stiff and cause deficits in communication with the horse (Deutsche Reiterliche Vereinigung, 1996). The rider is only able to adapt to the swinging motion of the horse if his musculature has a basic tone, but is also relaxed. The muscles of the torso flex and release automatically in harmony with the horse's gait (Wiemer, 2013). The head is held freely above the relaxed and slightly retracted shoulders, looking ahead and with the chin neither tucked nor pushed forwards. The arms should hang by the sides just in front of the vertical with the forearm forming the extension of the reins and the elbows touching the torso (Schnitzer, 2013). Only the supple and relaxed seat allows for the rider to give leg and rein aids independently from the movement of his torso. For the correct and effective communication, this is an indispensable condition (Deutsche Reiterliche Vereinigung, 1996).

Recent research has suggested that core stability training has a positive effect on achieving this position (Terada *et al.*, 2004; Wilkinson and Graham, 2008; Sudhoff, 2010; Boden *et al.*, 2014). If the rider has poor core stability chronic postural effects are usually apparent, which will cause muscle asymmetries. Muscular asymmetries in the rider may be compensated for in the horse and therefore result in hypertrophy/atrophy in the lumbar-sacral region (Goldspink, 1999). Because horse riding can only be performed when the rider is seated on the horse, the training of the combination is usually limited to riding instruction of the pair. This is unlike other popular and traditional sports that are commonly supplemented by cardiovascular conditioning and/or strength training to improve athletic performance (Reilly, 2006). Recent research has, however, suggested that horse-riding performance is improved by secondary exercise (Wilkinson and Graham, 2006; Sudhoff, 2010; Boden and Randle, 2012). This is also supported by the British Equestrian Federation's long-term participant development (2014), who suggested researchers investigate further. Cardiovascular fitness has been investigated across the disciplines and will be further discussed in Chapter 2.7, but kinematic variables of riding position have to date only been investigated in the dressage seat.

2.5 Anatomy of spine and pelvis

Commonly the spine is divided into three main areas: the cervical, thoracic and lumbar spine and the coccyx. These areas are made up of individual bones called vertebrae. The cervical spine consists of seven, the thoracic spine of twelve and the lumbar spine of five vertebrae. Additionally, there is the sacrum that is fused to the pelvis (Tittel, 1985). The pelvis acts as a link in transferring movement. Apart from the sacrum it consists of the ilium, ischium and pubis which form a bony ring (Figure 2.4). In terms of functional anatomy this means that every movement of the pelvis will also result in movement of the hip joint and the lumbar spine (Dietze, 2003).

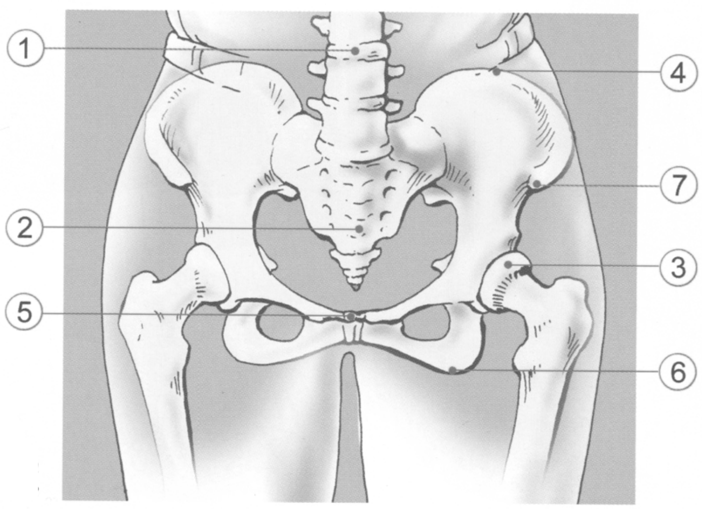

Figure 2.4: The pelvis with hip joint and lumbar spine from an anterior view. 1) lumbar spine; 2) sacrum; 3) hip joint; 4) iliac crest; 5) pubis; 6) ischial tuberosities; 7) iliac spine. (*Source:* Dietze, 2003)

This region of the trunk is also considered the powerhouse or core. The muscles of this area are crucial in posture stabilisation as well as generation of power (Muscolino and Cipriani, 2004). The core muscles are discussed in more detail in Section 2.11. The medial seat of the horse rider is achieved when equal weight is distributed through both left and right ischial tuberosities as well as the most inferior point of the pubis (Figure 2.5) (Dietze, 2003).

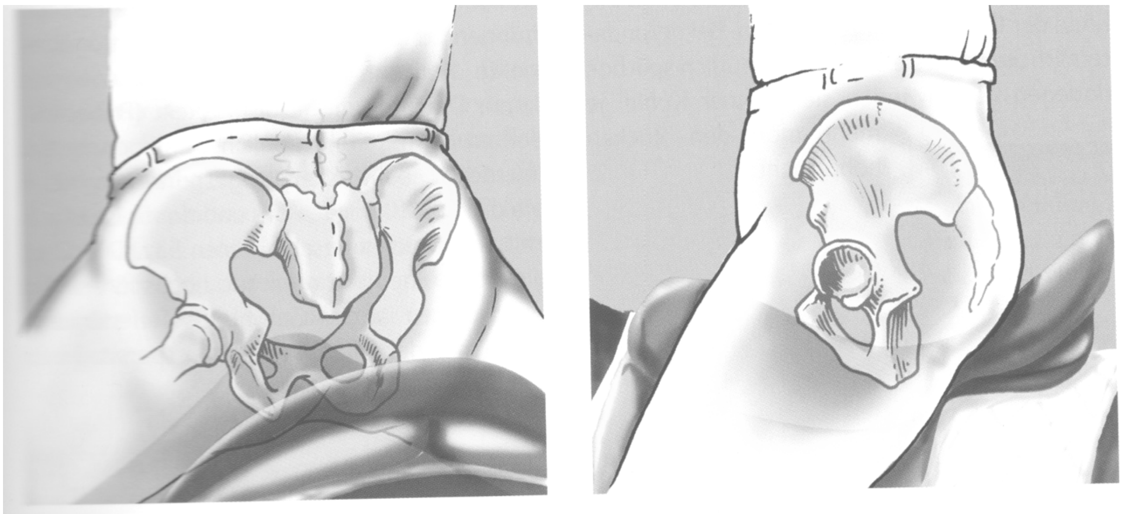

Figure 2.5: Posterior and lateral views of the pelvis in the saddle demonstrating how and where the rider sits. (*Source:* Dietze, 2003)

Female pelvises are larger and broader, whereas the male pelvis is narrower, taller and more compact and thus ideal for locomotion (Tittel, 1985). Furthermore, the *ischial tuberosities* are further apart in females, providing a wider base of support in seated position (Gray, 1987). Males have been found to have a greater loss in lumbar lordosis from standing to seated position (Bridges *et al.*, 1992). This occurs as a result from the posterior tilt that males commonly adapt during seated position. Females, however, tend to rotate the pelvis anterior during sitting (Dunk and Callaghan, 2005), and have also been found to be more static, upright sitters (Gregory *et al.*, in press), which has been found to take more muscle activity than a slumped and even standing position (Callaghan and Dunk, 2002). Males are advised to acquire greater lumbar support to increase lordosis during sitting and decrease the risk of injury (Dunk and Callaghan, 2005). Even though equestrianism is one of the few sports where male and female athletes are competing against each other, the anatomical differences suggest that the mechanics of riding position are not entirely the same.

2.6 Muscle characteristics

Muscles are made of bundles of fibre that produce and are powered by Adenosine Triphosphate (ATP). Different types of muscle fibres have varying metabolic capacity to continuously provide ATP. Type I muscle fibres have a slow contraction velocity, which makes them nearly resistant to fatigue (Burke *et al.*, 1973). These fibres are mainly found in a stabilising function, such as postural muscles (Armstrong and Phelps, 2005). Type II muscle fibres have a fast contraction velocity. Their metabolic capacity is too slow to continuously provide enough ATP making them prone to fatigue after only a relatively small capacity of activity (Jones *et al.*, 2004). Skeletal muscle is voluntary, i.e. we can consciously control it, as well as it reacting out of reflex. The purpose of muscles is to bring movement to the skeleton through generating force that acts on the tendons, which are connected to the bones (Silbernagl and Despopoulos, 1979). Most muscles are arranged in antagonistic pairs. These pairs consist of the agonist, the muscle that produces force in one directing and the antagonist, the muscle that acts against the agonist to slow down action or produce countermovement (Waugh and Grant, 2006). As an example of this the abdominals and lower back muscles can be used. If these muscles would not work as an antagonistic pair the body would either be constantly bent over or leaning backwards. In horse riding the interaction between these muscles allows for the rider to maintain a quiet and balanced upper body.

The properties of muscles are excitability, contractibility, extensibility and elasticity. Stretching can be applied; however, this is passive activity (Biewener, 2003). Skeletal muscle function is defined by the two phases of contraction and relaxation. Contraction occurs in response to a stimulus received at the neuromuscular junction from the brain via the spinal cord (Waugh and Grant, 2006). The shortening and thickening that is the result of muscle contraction pulls the attached bones together and thus results in flexion of the joint (Silbernagl and Despopoulus, 1979). Even when resting nerve pulses are still being received by the muscles to maintain structure. This baseline contraction is known as muscle tone (Jones *et al.*, 2004).

To facilitate a variety of tasks three types of muscle contraction are being used by the body: concentric, eccentric and isometric. Concentric contraction results in shortening of the muscle and occurs when the muscle generates enough tension to overcome resistance (Adrian and Cooper, 1995). When looking at the example of the abdominals: concentric contraction is needed to perform the upward lifting of the trunk when performing a crunch. Eccentric contraction occurs when the muscle is holding against a movement without eliminating it; in our case the trunk being lowered back onto the floor. During this type of contraction, the muscle is lengthened, usually in the same direction as the force (Enoka, 1996). Concentric and eccentric contractions are classed as isotonic due to the self-initiated change in muscle length (Nordin and Frankel, 1989). In functional exercise the constant change between concentric and eccentric contraction that is necessary for most tasks is known as the stretch-shortening cycle (Adrian and Cooper, 1995). The last type of contraction is static and known as isometric, because the length of the muscle does not change. Tension that is developed because of loading is not relieved either because the resistance is too heavy or the antagonistic muscle prevents the movement (Jones *et al.*, 2004). In the example of abdominal crunches this could mean that the body is being held in mid-air or that someone may be pushing down on the chest making it too difficult to lift the trunk off the floor.

2.7 Principles of training

Specificity

Each particular sport places a unique metabolic and biomechanical demand on the athlete (Kibler and Chandler, 1993). Sport-specific conditioning programmes are believed to contribute best to performance enhancement and injury prevention (Reilly, 2006). General exercises are important as a baseline for more specific skills (Prentice, 2010) and some believe that transferability of skill between tasks is an automated response (Adams, 1987; Mouchnino *et al.*, 1992; Kioumourtzoglou *et al.*, 1997). Asseman *et al.* (2004) argue that skill is not transferable between activities. When considering that improving the functional biomechanics of a joint requires exercises involving that particular joint, this seems coherent (Mackenzie, 2004). Stretching the shoulder joint, for example, would not be expected to improve the flexibility of the hip and even less so the VO^2max.

In further studies Asseman *et al.* (2008) argue that skill may be transferable if it had been trained in a situation that is similar to the one that is to be improved. The subject of their studies were gymnasts who performed better than non-gymnast subjects when balancing on one leg; however, the subjects showed no difference standing on both legs or on one leg with their eyes closed. After a period of the specific position they did perform significantly better. Considering that their training involved keeping balance on one leg, but not with closed eyes this seems to suggest that skills are transferable within similar situation, but will require additional training for slight changes in the task. Other studies support these findings (Bachmann, 1961; Henry, 1968; Schimdt and Young, 1987; Hugel *et al.*, 1999; Vuillerme *et al.*, 2001). It should be noted that the majority of this research has been conducted with gymnasts, who can be considered to have a more efficient and sensitive sensory system than other athletes (Vuillerme *et al.*, 2001). \

Overload

Mobility exercises should be performed to the full potential of an athlete's range of motion, known as the active end position. Only at or beyond active end position mobility can be increased. This can be achieved with an external force bringing the limb further than the active muscle contraction can or in dynamic exercises, where the active end position is passed through the force of the momentum (Kurz, 2003). Muscle strength can only be improved when the muscle is working harder than usual. To retain training responses the stimulus needs to be gradually upgraded through increased constant load, repetition, intensity or workload (Lawrence, 2007).

Recovery and Adaptation

During the rest period after the exercise the body adapts by increasing its ability to cope with the imposed loads. If no time for the recovery of the body is allowed, no training adaptation can be facilitated (Mackenzie, 2004). In exercises lasting up to 60 seconds the glycogen storage is improved, whereas in short exercises up to ten seconds glycogen stores in the muscles are increased (Prentice, 2010). Hypertrophy of the muscles is the most obvious adaptation to training (Jones *et al.*, 2004). Adaptation takes place after about six to eight weeks (Bean, 2005).

2.8 Aerobic Fitness

Aerobic fitness is the ability to extract and utilise oxygen from the atmosphere. It relies on the lungs, heart and vascular system to absorb and transport the oxygen to the muscles, which then extract the oxygen from the blood and generate ATP in the muscle cells (Waugh and Grant, 2006). ATP is the fuel that provides energy to the muscle. Aerobic fitness is measured by VO^2max, which is the maximum capacity of the body to utilise oxygen (Schell and Leelarthaepin, 1993). Women are known to have lower VO^2max capacities than men and the capacity also decreases incrementally with age (Hill and Smith, 1993).

The main influence on VO^2max is the heart's ability to pump blood around the body to supply the muscles with oxygen (Seeley *et al.*, 2003). Aerobic exercise training has shown to increase the stroke volume as well as size and contractility of the heart muscle. With the higher amount of blood being pumped around the body the heart needs to work less hard at rest, which results in a lower resting heart rate (Schell and Leelarthaepin, 1993). The production of ATP is facilitated by the mitochondria of the muscle cells that transform carbohydrates and fat into energy (Jones *et al.*, 2004). The body is only able to produce so much ATP, but exercising at the aerobic threshold will increase aerobic capacity over time (Hale, 2003).

Physiological demands of horse riding have been investigated and research shows that aerobic demands are higher in those disciplines that require galloping and jumping, such as eventing (Roberts *et al.*, 2009), show jumping (Guitérrez Rincón *et al.*, 1992), racing (Trowbridge *et al.*,1995) and polo (Wright and Peters, 2008). No baseline aerobic capacity was established between the studies for horse riders, which was suggested to be due to different testing modalities (Douglas *et al.*, 2012) for which bicycle ergometry (Westerling, 1983; Devienne and Guezennec, 2000) and treadmill protocols have been used (Meyers and Stirling, 2000; Meyers, 2006). The reported VO^2max was higher in the studies where a cycle ergometer was being used, which could be because on the cycle ergometer the fitness of the whole body is challenged less than on the treadmill. The high upper and total body work that is required in horse riding can therefore not be reproduced accurately. Another reason for this might be the validity of cycle ergometry, which has shown to under predict maximal oxygen uptake by other authors (Withers *et al.*, 1981; Mazzeo and Marshall, 1989). Westerling, (1983) also found higher aerobic power in the more experience riders. Generally, it can be said that riding, particularly in the forward seat has a high aerobic cost (Guitérrez Rincón *et al.*, 1992; Trowbridge *et al.*, 1995; Wright and Peters, 2008; Roberts *et al.*, 2009), but equestrian athletes are considered to have a low aerobic capacity, particularly when compared to athletes of other disciplines (Davies and Thompson, 1979; Devienne and Guezennec, 2000; Meyers and Stirling, 2000). Meyers (2006) investigated the effect a 14-week horse riding training programme (walk, trot and canter) would have on VO^2max in 15 female horse riders. The riders were required to ride five times per week. No significant improvements were found suggesting horse riding alone was not sufficient to improve aerobic capacity. These results could also be down to the level of experience of the riders, because Meyers and Stirling (2000) and Meyers (2006) used amateur riders as opposed to the professionals by Westerling (1983), Guitterrez Rincon *et al.* (1992), Trowbridge *et al.* (1995) and Wright and Peters (2008). This potentially indicated that the professionals spend a greater amount of time in the faster gaits and jumping, which have a higher aerobic cost, and therefore have better aerobic fitness in comparison to the amateurs. Considering that men and women compete on equal terms in equestrianism suggests that cardiovascular fitness is no limiting factor (Hill and Smith, 1993).

2.9 Flexibility

The extent of flexibility depends on the nature of the joint (ball and socket, hinge, etc.) and properties of the involved connective tissue (Kurz, 2003; Bishara *et al.*, 1998). Common movements are flexion and extension, abduction and adduction (Figure 2.6), and rotation.

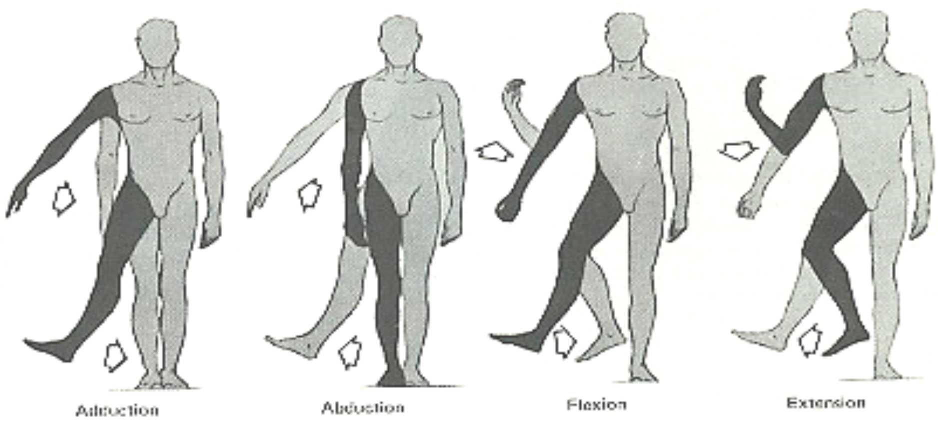

Figure 2.6: Common joint articulations. (*Source:* Keefer, 2005)

Flexibility is necessary for ideal posture; long and strong muscles keep the body in good alignment and reduce the risk of back pain (van Tulder *et al.*, 2000). Often flexibility training to increase Range of Motion (RoM) of one or several joints in extent and direction is neglected in exercise programmes. Flexibility can be assessed static and dynamic (Lucas and Koslow, 1984). Flexibility is influenced by lack of activity, muscle imbalances and heredity and tends to decrease rapidly with age (Bishara *et al.*, 1998). Extremes in flexibility such as hyper and hypo mobility of a joint increase the risk of injury. Stretching is an effective physical exercise to increase muscle length and thus flexibility (Lucas and Koslow, 1984). Stretching can be active or passive. During active stretching antagonist muscles are contracted to stretch the agonist muscles. Passive stretching involves external forces stretching the muscles, for example hands pulling toes towards the trunk, stretching the muscles of the back of calf and thigh (Kurz, 2003). The most effective way of stretching is Proprioceptive Neuromuscular Facilitation (PNF). This is a combination of active and passive stretching, which promotes an increase in strength (Funk *et al.*, 2003).

Flexibility has been found to be an important variable in rider position, with lacking flexibility causing postural mal-alignment (Terada *et al.*, 2004; Dietze, 2003), and one of the key elements of advanced rider positioning was the ability to absorb the horse's movement through flexible joints (Wolframm, 2015). Sekendiz e*t al.* (2007) found that flexibility could be improved through Pilates training. Riding specific flexibility of especially the legs is important and facilitated by the hip flexors. Independent movement of the upper and lower leg is commonly impaired by tight muscles. If the quadriceps muscle is tight, as it is when the rider grips with his knees, the lower leg is drawn forward and loses the ability to operate independently (Stewart, 2004), which will result in the loss of communication between the rider's lower leg and the horse.

Tight muscles are not able to absorb energy due to lack of contraction – relaxation capacity (Adrian and Cooper, 1995). For example, a rider with tight back muscles leans backwards and limits both energy transfer and independent use of other muscle groups (Dietze, 2003). Stabilisation of back and shoulders in this position could be achieved through increased rein contact, but this would compromise the horse's performance (Dietze, 2003). In order to sit deeply in the saddle, the rider's seat needs to be balanced on the two *ischial tuberosities* (seat bones) and the lowest point of the pubic bone with the legs relaxed and stretched (Sommermeier, 2002). Even though flexibility has been determined a key aspect of riding skill, little research has been carried out investigating its impact on riding position and performance.

2.10 Balance

Balance is the ability of a body to continuously adapt to forces in order to maintain a transitory dynamic equilibrium before advancing and attaining a new equilibrium (Adrian and Cooper, 1989). Because balance enables the body to remain in an upright position it is involved with nearly all bodily actions from standing to moving about in a variety of ways. When balance needs to be maintained in a set position for any amount of time it is commonly referred to as static balance. Most sports rely on dynamic balance, which is the ability of an athlete to maintain stability whilst in motion (Lloyd *et al.*, 2006). To establish balance several bodily systems that are involved with proprioception are required.

Vestibular system

The vestibular system, a complex apparatus located in the inner ear, is able to provide information about the movement of the head attained via sensors (Tittel, 1985). These sensors pick up on the position of the head in respect to gravity, i.e. whether the head is straight, tilted or upside down. Furthermore, the vestibular apparatus notices the speed at which the head is moving and can distinguish between directions (Schmidt and Lee, 2005).

Visual system

The visual system relies on the eyes, its receptors, to inform the brain about where in space and in relation to objects or other people are in its view (Schmidt and Lee, 2005). Visual proprioception is the most salient source of special orientation (Lloyd et al., 2006). Vision as an impact on balance was observed by Lee (1988) who found a higher body sway in the visually impaired in comparison to sighted people as well as a less stable posture in the sighted when blindfolded. The effects on dynamic balance as well as a safe and efficient manner of locomotion have also been found to be highly reliable on visual cues (Warren and Whang, 1987).

Somatosensory system

The somatosensory receptors provide information about the body's location in space as well as the body's parts in relation to each other and the loads experienced by the body (Lloyd et al., 2006). The joint receptors inform about joint position, whilst the muscle receptors report muscle length and tension and the cutaneous receptors provide a sense for movement and load (Schmidt and Lee, 2005).

Centre of Gravity

The Center of Gravity (CoG) is an imaginary point in the body where all forces acting upon it, are balanced. The location of the CoG is influenced by posture and movement (Hasan *et al.*, 1996). It can lie within or outside the body; however, for the body to be in balance it must lie in an area within or directly above the base. The greater the base is, the greater the range of support, because greater displacement of bodily parts is needed to move the CoG outside of the base area, which can be any part of the body (Murray *et al.*, 1967). In ballet dancers, the base are the toes. In gymnasts it can sometimes be the hands. Riders' base of support are the buttocks (Hof *et al.*, 2005). The lower the CoG is, the more stability the body has (Adrian and Cooper, 1995), which is why in some sports, such as wrestling or ice hockey, the trunk is carried closer to the ground (Lloyd et al., 2006). All bodily segments can be moved to different positions; however, the better aligned the body is above the base, the more stability can be provided and the lower the rate of muscle fatigue (Hof *et al.*, 2005). Flexion and Extension of the hip is used to move the Centre of Mass (CoM) forwards and backwards to maintain balance (Buckley *et al.*, 2002).

Postural control

Coordination and timing as well as muscle strength are essential to maintain balance (Vrieling *et al.*, 2008). In the athlete both these factors are thought to be modified and are likely to be affected by technique. The ability of a person to balance, however, is heavily reliant on neuromuscular control, which is demanded in heightened amount in technical acrobatic sports. A study by Gerbino (2007) supports this theory, who found that ballet dancers have better proprioception of motion and placement. Core stability is also thought to be a crucial factor for good balance (Fitt *et al.*, 1993; Argo *et al.*, 1999; Mullhearn and George, 1999). Only when large enough forces to uphold stability can be generated during voluntary movement is balance control achieved (Ledin *et al.*, 2004).

Balance training

Balance training is known to have a positive impact on postural skills (Sayenko et al., 2012; Oliveira et al., 2013) and improved balance performance has been reported to be due to adaptations in the Central Nervous System (Taube et al., 2008). Trimble and Koceja's (2001) study showed that postural skill correlates with the plasticity of the CNS and the improved postural control is thought to be due to spinal adaptations (Gruber et al., 2007; Taube et al., 2007). The findings of these same studies also suggest that the excitability of spinal reflexes is reduced by balance training. Taube et al. (2008) hypothesised that balance is improved through the reduced excitability, which is believed to eliminate involuntary postural sway. More recently Nagai et al. (2012) reported a relationship between reduced co-contraction of agonist and antagonist muscle groups and improved balance performance. This is thought to be particularly influential in demanding postural tasks requiring accurate balance control. These advances in neuromuscular efficiency are responsible for improved motor control and enhanced postural skills.

In a systematic review Orr *et al*. (2008) recently suggested that resistance training in isolation is not a reliable way to improve balance in older adults. Reason for this belief is that in the intervention general muscles for body strength were used rather than identifying muscles used in balance control. Hill et al. (2005) found that a combination of yoga and tai chi significantly improved balance as well as strength and gait control. Considering the importance of muscle strength and flexibility for the maintenance of balance these findings are not surprising as both tai chi and yoga involve elements of resistance training as well as stretching. Other exercises such as Pilates, dance, walking and a combination of exercises may also be suitable as balance training (Heyward and Gibson, 2014). Other tools that are frequently used in balance training are balance discs, foam pads or rollers, balance boards and stability balls. All of the above methods of balance training were used to improve standing balance. It is unclear if these methods would also improve seated balance, and even though riding position is considered to be more like standing with flexed and abducted legs, if they would have an impact on balance in riding position.

There are no firm recommendations on the prescription of balance training; however, a client/purpose based approach is advocated (Heyward and Gibson, 2014).

Research suggests that impaired balance in the elderly correlates to increased visual cues for postural control and decreased ability of the sensory systems to organise and select postural information (Manchester *et al.*, 1989; Horak *et al.*, 1989). An investigation by Shumway-Cook *et al.* (1997) found that balance and mobility in older adults improved significantly after an 8-week programme of multidimensional exercise.

Balance in horse riding

Research on the specific muscles (*rectus abdominis*, *erector spinae* and *adductor magnus*) used during riding was carried out by Terada *et al.* (2000), who looked at their activity and related function. Results showed, that coordinated contractions are stabilising the rider's position during the horse's gait and thus impact on the ability to coordinate movement, i.e. following the horse's motions. They concluded that because a high proportion of tonic contractions were found, muscle activity was predominately for co-ordination and postural stabilisation rather than to generate power. Compensation due to lack of muscle strength and therefore stability was also observed. An example is the overuse of the thighs (*adductor magnus* muscle) in novice riders for posture maintenance usually caused by lack of pelvic flexibility (Dietze, 2003).

Terada *et al.* (2000) also suggested that the experienced rider was able to gauge the horse's movement and could cope by instigating a balance in activity of the *rectus abdominis* and *erector spinae*. The muscles that have been classified as important to control the horse are *rectus abdominis, trapezius, serratus anterior, teres major, flexor carpi radialis, extensor carpi ulnaris, biches brachii, triceps brachii, middle deltoid* and sterna head of *pectoralis major* (Stewart, 2004). These are used in an isotonic manner to maintain position (Terada *et al.*, 2004). This research was taken further by Probin (2014) who found that in professional riders the more experienced show less muscle activity to administer aids to the horse in order to achieve specific movements. This would be in line with the findings of Terada *et al.* (2000) and would be explained by the more experienced rider being able to better gauge the horse's movement and therefore being prepared by instigating the right amount of muscle activity in order to maintain balance (Peham *et al.*, 2001). Lagarde *et al.* (2005) investigated the difference in phase synchrony between expert and beginner riders and found that the expert showed better temporal regularity of the oscillations of the horse's body. The beginner was lacking the "feel" to adapt to the horse's movement and therefore showed departures from the synchrony and also a tenser trunk, which is likely a result of not being able to follow the movement.

Lovett *et al.* (2004) investigated the changes in rider position in relation to the stride pattern of the horse. In agreement with Schils *et al.* (1993) they found that the trunk in rising trot is placed in front of the vertical. This finding is further supported by Kang *et* al. (2010). The biomechanical back model by Hess *et* al. (2012) describes anterior tilt of the pelvis resulting in a straightened back and shoulders shifted backwards (Figure 2.7). The centre of gravity is also moved anterior towards the horse's head (Betz *et al.*, 2005). Douglas *et al.* (2012) hypothesised that because the range of motion of the trunk angle was the same in walk and canter, but the ground reaction forces acting upon the rider were greater in canter, the muscle activity must also be greater.

Riding position stability was investigated in trot by Peham *et al.* (2011), who found that sitting trot showed the highest load on the horse's back, followed by rising trot and the two-point seat. This study also found that riding position was most stable in the two-point seat followed by rising and then sitting trot suggesting that a stable rider would result in less loadin of the horses back than an unbalanced one.

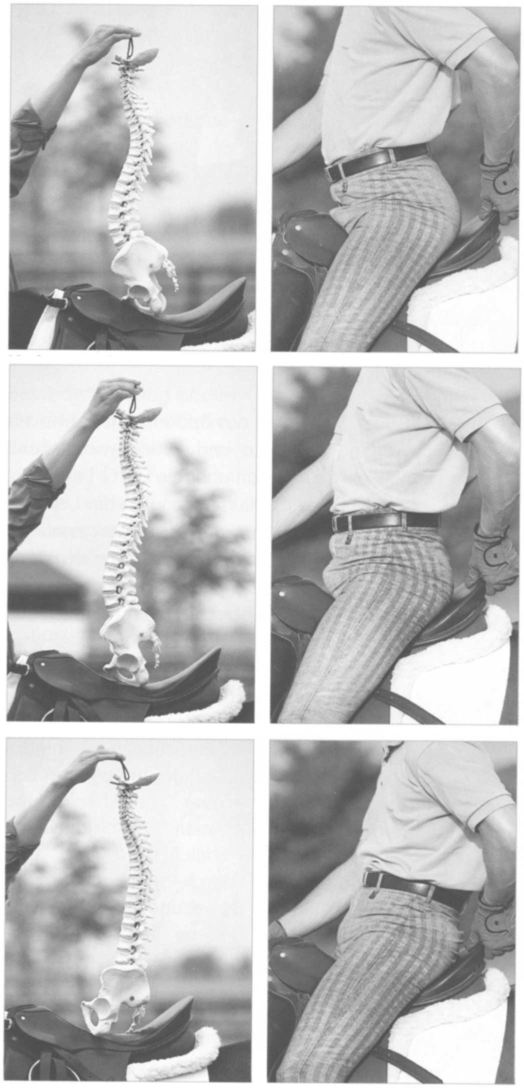

Figure 2.7: The biomechanical back model demonstrated showing the anterior tilted pelvis with increased lumbar curvature (top), the ideal alignment of the pelvis and spine (middle) and the posterior tilted pelvis with decreased spinal curvature. (*Source:* Dietze, 2003)

There has been no work carried out with the riders performing sitting trot. Maximal saddle pressure has been measured at the end of stance of the diagonal pair in trot (Freuhwirth *et al.*, 2004). Within a canter stride lower leg and thigh displacement was relatively small; trunk displacement was appreciable. On impact of the hind limbs the trunk was displaced behind the vertical, whereas on impact of the front limbs the trunk moved in front of the vertical. This could be based on the flexion and extension movements of the horse's spine during gait (Lovett *et al.*, 2004).

The horse's *tuber sacrale* were found to be at their lowest point at the beginning of stance and highest during mid-stance of front and hind limbs (Clayton, 1994). This indicates that the horse's CoG during canter is further behind during impact phase of the hind limbs and further forward beginning of stance in the front limbs (Figure 2.8). In trot, the CoG is fairly constant, depending on the level of collection the horse is working. In canter, the inner hip will be slightly forwards displaced and the outer shoulder must not stay behind. The seat must be soft in the saddle with a stable upper body (Deutsche Reiterliche Vereinigung, 1996).

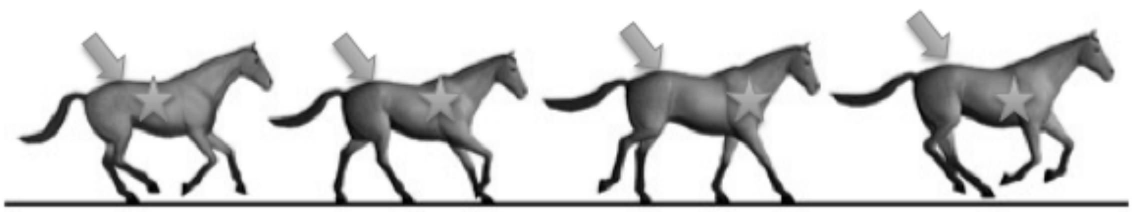

Figure 2.8: The stride cycle of right lead canter indicating the position of the CoG (star) and *tuber sacrale* (arrow) throughout. (*Source:* S.G. Equestrian, 2010)

2.11 Core stability

Anatomy and Physiology

According to Akuthota and Nadler (2004), ‘‘*the ‘core’ is described as a box with the abdominals in the front, paraspinals and gluteals in the back, the diaphragm as the roof, and the pelvic floor and hip girdle musculature as the bottom*.’’ These muscles allow for the transfer of energy generated by the lower body during exercise through the sacro-iliac joint and trunk to the upper body (Baker, 1999). The core is therefore sometimes referred to as the powerhouse (Muscolino and Cipriani, 2004). Skeletal components are the spine and the pelvis with the hip, lumbo-sacral and lumbar spinal joints (Muscolino and Cipriani, 2004). The main abdominals, also known as the spinal flexors, are said to be *M. transversus abdominis, M. rectus abdominis, M. obliquus externus abdominis* and *M. obliquus internus abdominis* (Kibler *et al.*, 2006; Muscolino and Cipriani, 2004). *M. transverses abdominis* is activated in mid-stance of the trot (Terada *et al.*, 2004). The paraspinals consist of the muscles that are alongside the spine, known as the spinal extensors. These include the *M. erector spinae, M. multifidi, M. quadratus lumborum,* and *M. transversospinalis* (Muscolino and Cipriani, 2004). The muscles in the hip and pelvis area with their large cross-sectional build up not only stabilise but also aid in power generation for sporting activities; however, in riding muscle force is rarely used for power generation, but rather for controlled, precise execution of movement. For example when throwing an object 50% of the force needed is generated in the hip/pelvis area (Kibler, 2006). The gluteals, for example, stabilise the trunk during motion over the limb, provide energy for forward leg movement and in riding stabilise the leg, preventing it to slide forward (Baechle *et al.*, 2000). The pelvic floor muscles or perineal muscles consist amongst others of the *M.*

levator ani, M. coccygeus and the deep and superficial transverse perineals (Muscolino and Cipriani, 2004). Tense pelvic floor or gluteal muscles during riding impede a deep seat (Stewart, 2004). The diaphragm can independently from breathing increase intra-abdominal pressure and thus increase trunk support. This is achieved through a more rigid cylinder for trunk support allowing for less strain on the spinal muscles (Cholewicki *et al.*, 1999; McGill, 2001) (Figure 2.9). Training of these muscles is thought to not only improve static posture but also dynamic strength and flexibility of the whole body (Muscolino and Cipriani, 2004). Equal development of left and right muscles is essential to maintain symmetry.

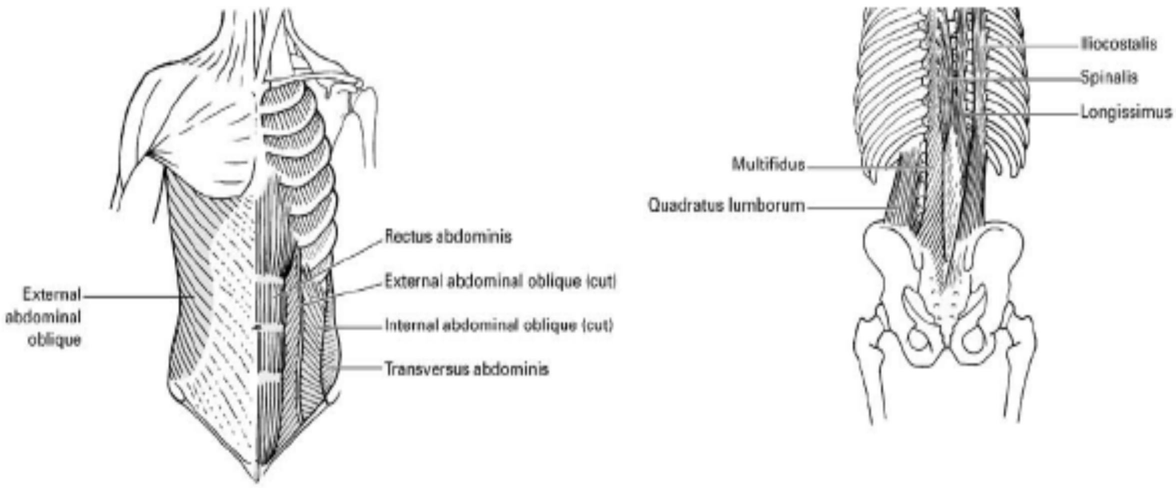

Figure 2.9: The muscles of the core. (*Source:* Muscolino and Cipriani, 2004)

Core stability

Although there is no one specific definition of core stability it is commonly accepted that this involves control over the trunk and its positioning above the lower limbs resulting in "*proximal stability for distal mobility*" (Kibler *et al.*, 2006). Mills *et al.* (2005) define lumbo-pelvis stability as the '*ability to control motion of the lumbar spine and pelvis relative to an arbitrarily defined neutral position'.* Jull *et al.* (1993) hypothesised that pelvic instability is indicated when the lumbar spine and pelvis move excessively and deviate from this neutral position. Core stability is said to be improved when core strength increases (Wilkinson and Graham, 2008); however, a difference between core stability and core strength must be noted. Core strength implies muscle strength and endurance of the core muscles whereas core stability is concerned with control of kinetic chains (Kibler *et al.*, 2006). Core strength is one of the variables of core stability along with motor control, balance and postural control (Bliss and Teeple, 2005). Because the principle is based around the main factor of control, core stability is hard to measure directly (Akuthota and Nadler, 2004). Core strength is commonly accepted as an indicator, but may not correlate directly with stability (Cholewicki *et al.*, 1997; Cholewicki and McGill, 1996; Akuthota and Nadler, 2004). Sekendiz *et al.* (2007) found that core muscle training encourages strength development of the abdominal and lower back muscles; the study by Carpes *et al.* (2007) on lower back and pelvis kinematics supports these findings and extends that the core training also influenced body balance.

In standing posture, the Centre of Mass in females has been found to be 4.6cm anterior to the spine, causing a continuous forward flex and relying on the back-extensor muscles to counteract this movement (Dunk and Callaghan, 2005). The external influence imposed in the spine by a moving horse requires increased stabilisation through muscle force (Jenkins, 2001). Unbalanced or weak back muscles therefore cause spinal instability resulting in poor posture (Schamberger, 2002)

Core stability training

Core stability training emerged in the late 1990’s mainly to decrease lower back pain (Ledermann, 2010). The coherence of core stability and lower back pain derived because studies had shown that patients suffering from injury related or chronic lower back pain showed a change in onset timing of the abdominal muscles (Hodges and Richardson, 1996). Since then core stability training has been analysed in research and the main purpose has been diversified to not only control lower back pain, but also to amend posture, decrease the risk of injury and increase athletic performance (Kibler *et al.*, 2006; Mills *et al.*, 2005; Akuthota and Nadler, 2004). Performance is thought to be improved through increased muscle endurance, core strength and stability, achieved through specific, functional training; however, Asseman *et al.* (2004) have found that postural control is exercise specific and not transferable.

There are several methods of increasing core stability available, such as yoga (Omkar and Vishwas, 2009), abdominal exercise on a swiss ball (Duncan, 2009; Willardson, 2007) and Pilates (Sekendiz *et al.*, 2007; Johnson *et al.*, 2007). Bliss and Teeple (2005) suggest that all exercise should be centred around core strengthening and stability training. These methods recruit and therefore overload core muscles, resulting in training adaptation and efficiency development of neuromuscular pathways (Mackenzie, 2004; Curnow *et al.*, 2009).

2.12 Posture

Posture is variously defined as "*the configuration of the musculoskeletal system in achieving activities of daily living against the forces of gravity*" (Humphreys, 2008). This position can be either intentionally or habitually assumed and applies to upright stance as well as unsupported sitting and prone lying (Trew and Everett, 2005). In the context of equestrian sport, we are less interested in the posture the body assumes when lying down, as riding position is more like a combination of standing and sitting posture.

Ideal posture

Good posture involves training the body to stand, walk, sit and lie in such a position where the joints and bones are lined up in a way that muscles are used in the most efficient way producing the least amount of strain on muscles and ligaments possible and preventing the spine from becoming fixed in abnormal positions (Massey, 2009). The consensus for ideal posture is that the line of gravity intersects the tragus of the ear, just anterior to the shoulder joint, just posterior to the hip joint, just anterior to the knee joint and just anterior to the ankle joint on the sagittal plane. The lateral line of gravity should ideally intersect the occipital protuberance, the C7 and L5 spinous processes, the coccyx and bisect the knees and ankles. Both these views of ideal posture are displayed

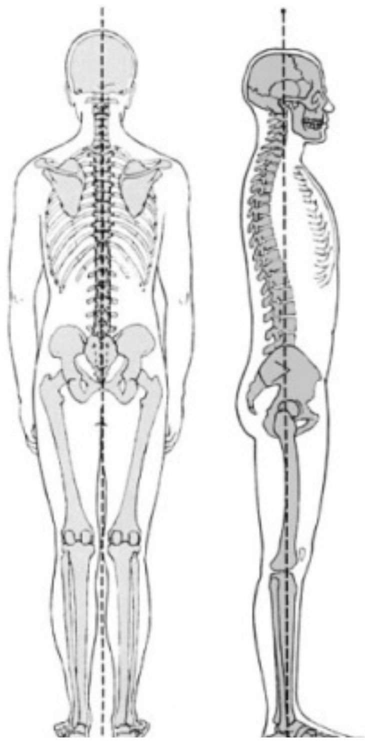

Figure 2.10: Lines of gravity in ideal posture from a posterior (left) and lateral (right) view.

in Figure 2.10 (Brunnstrom, 1954; Kendall *et al.*, 1983; Woodhull *et al.*, 1985; Pearsaii and Reid, 1992; Caron *et al.*, 1995; Massey, 2008).

Spinal posture

The 'S'-shaped spinal curvature, shown in a lateral view of the body in Figure 2.10, approaches adult form by the time children reach the age of six years old (Cech and Martin, 2002). During puberty, the supporting structures of the spine are challenged by the increased speed of growth and leave spinal posture vulnerable to formation stressors (Nissinen *et al.*, 1993). Spinal curvature reaches maturity once growth has finished by the age of 22 years. At this point the position of the centre of gravity (COG) has also developed (Nissinen *et al.*, 1993). In ideal alignment, the COG of a human is located at about the second lumbar vertebra; however, this changes position during movement (Horstmann and Dietz, 1990).

Posture and Balance

When critically evaluating the statement that was made at the beginning of this chapter it can be said that balance is the ability to sustain posture. The postural control cycle consists of the sensory information input, integration and effector result. The input requirements are met by the vestibular, visual and somatosensory systems. The output from the vestibular and visual systems is integrated at several different points in the brain (Shumway-Cook and Woolacott, 2001) whereas the somatosensory system is able to influence motor output at a spinal level. All systems respond to slightly different external influences with some overlap (Rothwell, 1994; Lee, 1988). Even though this is not complete, only one system is needed to establish effective balance. In most circumstances, the vestibular system is suggested to be critical in establishing external environments (Cech and Martin, 2002; Lee, 1988). In the final stage achieved and desired outputs are analysed to allow for modification of signal output. The multisensory input is crucial for the body's orientation within surroundings and enables movement control (Lackner and DiZio, 2000).

Postural muscles

Strong postural muscles allow for stable and upright posture. Aligned posture with normal spine and pelvis position is the optimal base position enabling most efficient muscle usage and least risk of injury (Wilcox-Reid, 2008). The high proportion of Type I fibres in postural muscles prevent early onset of fatigue (Burke *et al.*, 1973); however, weak postural muscles will fatigue quicker. Posture is affected negatively, as muscle fatigue has been shown to increase static body sway (Corbeil *et al.*, 2003; Ledin *et al.*, 2004). Long term body sway will lead to muscle imbalances, i.e. shortening of some and over stretching of other muscles (Muscolino and Cipriani, 2004). The main postural muscles and their function are described in Table 2.2 and shown in Figure 2.11. These are mainly the same muscles as those that provide core stability.

Table 2.2: The main postural muscles and their functions.

Postural muscle	Function
Trapezius	• Anchor the shoulder blades to the spine
Erector spinae	• Consisting of the spinalis, longissimus and iliocostalis • Extension sideway flexion of the spine
Multifidus	• Connecting the vertebrae
Rectus abdominis	• Controls the pelvis and curvature of the spine
Oblique muscles	• Rotation of the spine and torso • Bending sideways
Transversus abdominis	• Spinal protection and stability
Iliopsoas group	• Consisting of the iliacus and the psoas muscles • Hip flexors and low back stabilisers
Pelvic Floor muscles	• Consisting of the levator ani and the coccygeus muscle • Control of lumbar spine and pelvis (Hdoges *et al.*, 2007)
Deep Gluteal muscles	• Consisting of the piriformis, obturator internus, and gemellus inferior • Antagonist to the hip flexors
Hamstring	• Consisting of the biceps femoris, semimembranosus and semitendinosus • Stabilisation of the pelvis (Dowling and Hruska, 2003)

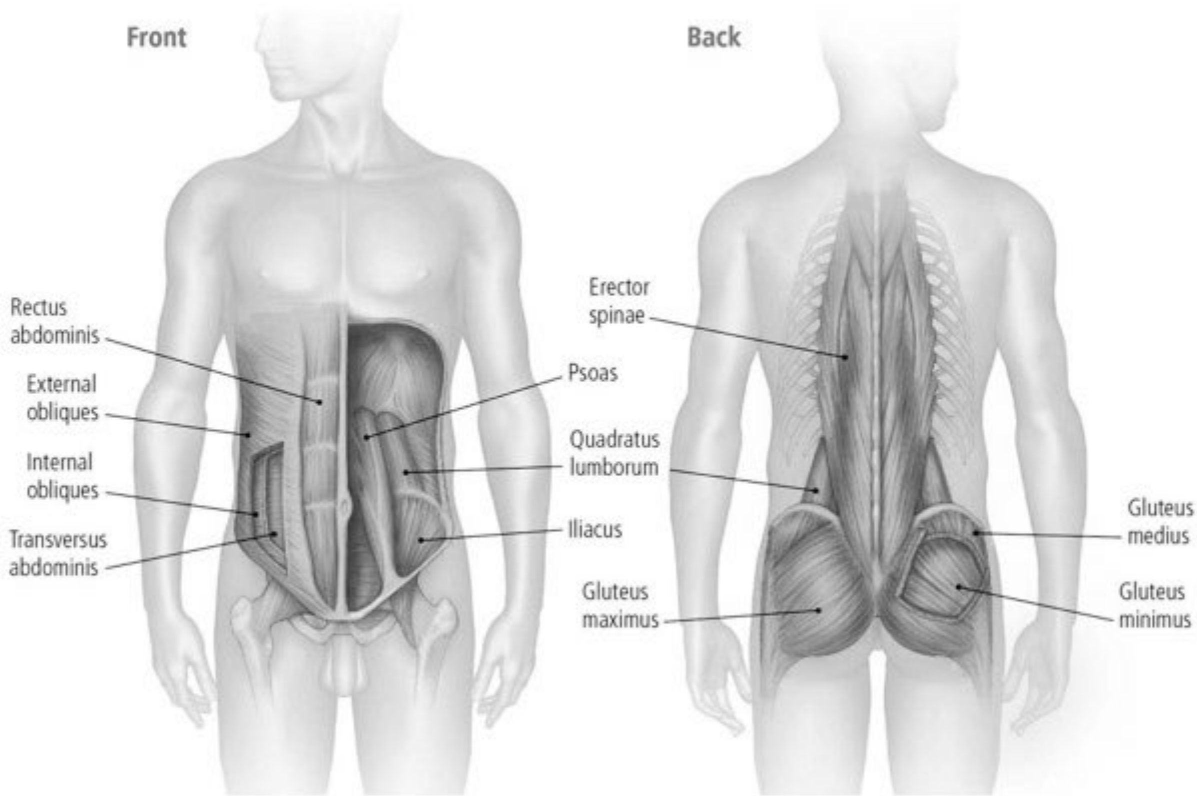

Figure 2.11: Anterior and posterior view of the main postural muscles. (*Source:* Harvard Medical School, 2013)

Abnormalities/faults

The most commonly observed postural deviations are listed in this section. All deviations from ideal posture cause increased muscle strain to compensate. The NHS (2013) identifies poor posture as a source of energy wastage and can often cause problems (Jackson *et al.*, 2004). The pelvic mechanics of the muscular balance of the leg, back and abdominal muscles is demonstrated in Figure 2.12. Weakness and tightness in any of the muscles involved is likely to result in postural defects.

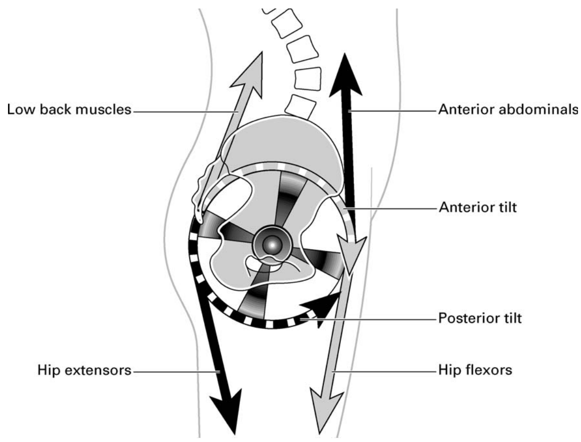

Figure 2.12: Mechanics of anterior and posterior pelvic tilt. Tightness in low back muscles and hip flexors would result in an anterior pelvic tilt with weak anterior abdominals and hip extensors. Tightness in anterior abdominals and hip extensors with weak low back muscles and hip flexors results in posterior pelvic tilt. (*Source:* Muscolino and Cipriani, 2004)

Lordotic posture

Even though a degree of lordotic curvature (concave or curving inwards) in the lumber spine is essential for a healthy back, excessive lordosis is considered as abnormal posture (Figure 2.13). Signs of lordotic posture include an anterior tilt of the pelvis and a flexed hip position. The cause of this abnormal posture is considered to be due to an imbalance of muscle strength or tightness. This postural fault can be either static or mobile (Dietze, 2003). The following imbalances are likely to be present:

- Lengthened or weak rectus abdominis and external obliques
- Lengthened, weak or underactive gluteus maximus and medius
- Lengthened hamstrings that may or may not be weak (Semimembranosus and semitendinosus)
- Overactive and tight hamstrings (Biceps femoris)
- Short and strong low back and hip flexor muscles
- Tight adductors due to flexed hip position

(Palastanga *et al.*, 2002; Massey, 2008)

Kyphotic posture

The kyphotic posture is marked by an excessive curvature of the thoracic spine (Figure 2.13). Like Lordotic posture this can also be either static or mobile. Usually people with this kind of postural defect have their head and/or chin poking forward with their cervical spine in hyperextension. Another sign might be shoulder blades that are abducted from the trunk and a posterior tilt of the pelvis. Muscular deviations that are likely to be present are listed below:

- Upper trapezius shortened or overactive
- Thoracic extensors lengthened
- Pectoralis muscles shortened or tight
- Rectus abdominis tight
- Lower trapezius and serratus anterior lengthened or inactive
- Posterior deltoid lengthened
- Occasionally shortened hip flexors

(Massey, 2008; Trew and Everett, 2005)

Flat Back posture

People with this type of postural defect have the characteristic of a reduced lumbar curve as well as a forward thoracic curve which results in a head forward position (Figure 2.13). Typically, flat back posture is also indicated by hyper extended knees and a posterior pelvic tilt. People with long term slouched sitting postures are prone to develop this postural fault. The following muscular imbalances are usually apparent:

- Weak neck flexors
- Tight or short rectus abdominis (sometimes strong)
- Short and strong hamstrings
- Lengthened and weak hip flexors

(Massey, 2008; Trew and Everett, 2005)

Sway Back posture

This postural defect is indicated by an anterior tilt of the pelvis along with the hips pushed forward (Figure 2.13). The natural lordosis of the lumbar spine is often shortened and exaggerated, making a flattened impression, with the natural kyphosis of the thoracic spine compensating and thus lengthening and sometimes extending into the lumbar spine. Along with a posterior sway and level, but pushed forward pelvis this posture is also often marked with hyper extended knees. Typical muscular imbalances are listed below:

- Weak neck flexors
- Weak or lengthened thoracic extensors
- Weak and lengthened hip flexors
- Gluteals shortened or weakened
- Tensor fascia latae tight
- Hamstrings short and tight
- External obliques lengthened, internal obliques unchanged or shortened

(Massey, 2008; Trew and Everett, 2005)

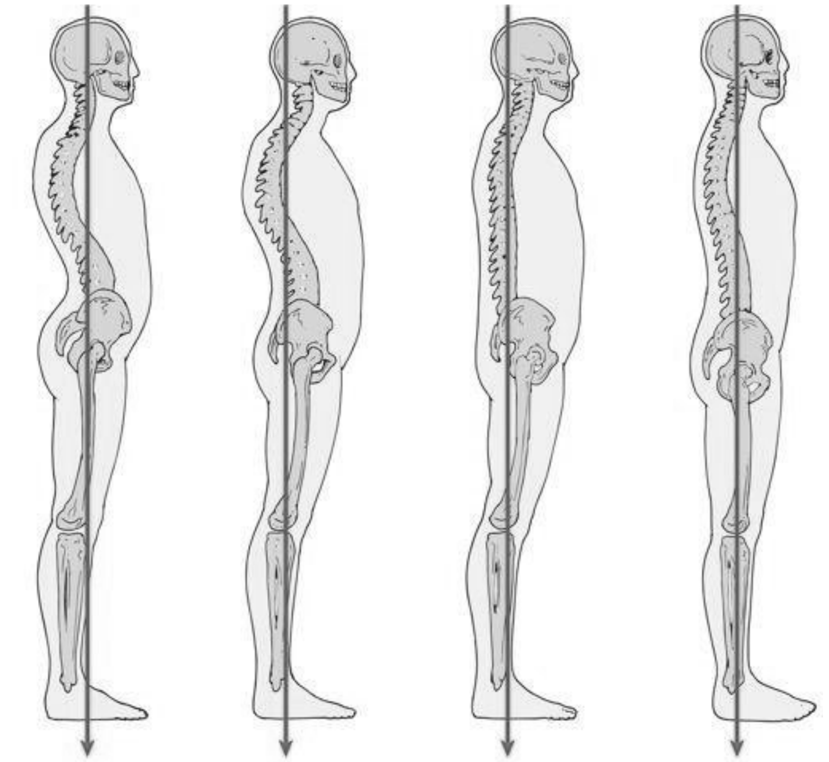

Figure 2.13: Common postural faults in spinal curvature from a lateral view compared to ideal alignment. (*Source:* Functional Strength, 2014)

Scoliosis

When looking at the spine from front or back a straight line should run through the vertebrae. Any malalignment of the spine will cause asymmetrical posture. A lateral curve usually seen in the thoracic or lumbar regions of the spine is considered as Scoliosis (Figure 2.14). This can be due to a defect from birth, but more commonly it is caused by tight and shortened soft tissues and muscles on the concave side while those on the convex side will be longer and weaker. In severe cases of scoliosis, a lateral flexion can be seen higher up the spine. In some cases, the scoliosis may be the compensation for a problem lower down the postural chain (unequal leg length, hip imbalances, etc.) (McGill, 2007; Trew and Everett, 2005).

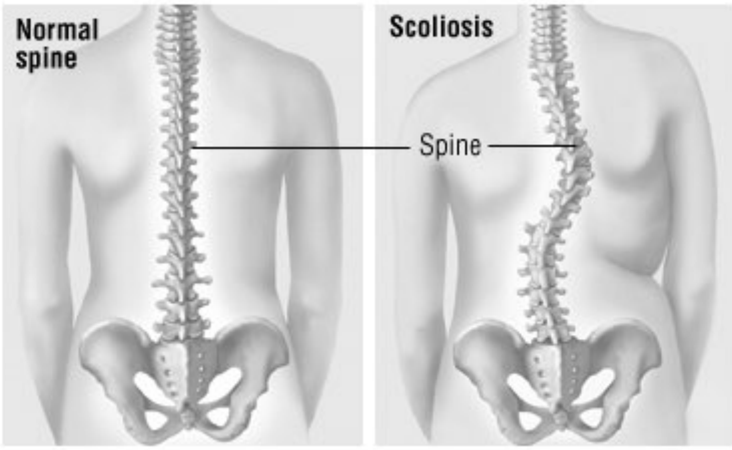

Figure 2.14: Comparison between the normal spine and abnormal curvature of Scoliosis from a posterior view. (*Source*: Sierra Neurosurgery Group, 2014)

Causes

Postural defects have a number of causes. These include skeletal imbalances, which are acquired naturally, such as inequality in limbs, disease, injury and habit (Solberg, 2007). The reader should note that deviations rarely originate within the spine itself but are often caused by muscular imbalances (Carpintero *et al.*, 1997). Another important variable on posture is habit. When the body is put in a position repeatedly the neuromuscular pathways learn and the new positioning is adapted, leading to altered posture (Curnow *et al.*, 2009). This process can both cause deterioration of posture and be used to retrain posture.

Posture in the equestrian athlete

Equestrian athletes are predisposed to a high likelihood of injury with the majority of injuries occurring during cross country. Most common are injuries to the shoulder, such as broken collar bones or dislocation (Ball *et al.*, 2007). Previous injury to the collar bone, neck, etc. may have a significant effect on human posture. Muscles in the area are kept still to restrict movement and thus prevent pain. Because of the compensatory actions during injury, muscles are trained incorrectly, causing postural asymmetry

(Solberg, 2007). An example of an athlete who has suffered a fracture of the collar bone, Lucinda Fredericks, a professional event rider can be listed. As can be observed in Figure 2.15 her left shoulder is higher than her right and she is holding her left wrist lower than the right, suggesting that rotation of the scapula is apparent.

Plate 2.1: Lucinda Fredericks' effect of collar bone fracture. Note the left shoulder rotated forward and the elbow protruding from the trunk. (*Source:* LIFE, 2014)

The anterior tilt of the female pelvis pushes the iliac crest forward during riding and thus lordosis of the spine is common in female riders. Since anterior pelvic tilt is a result of tight hip flexors and lower back muscles it could be argued that novice riders are especially prone, as their trunk was found to be in front of the vertical (Schils *et al.*, 1993; Lovett *et al.*, 2004). During a normal riding session most time is spent in trot (Clayton, 1993), with the novice rider spending most of that time in rising trot. The biomechanics of the rising trot are similar to squats, thus strengthening the *quadricep* muscle (Delavier, 2010) and further limiting correct riding position (Dietze, 2003).

Overuse of the back due to poor posture on and off the horse leads to back injuries (Mair *et al.*, 1996). Riding position in which the novice female tends to tip forward exaggerates these problems. For equestrians, there are other variables that may lead to asymmetry and thus back problems such as the one sided mucking out, carrying of water buckets, picking out feet, etc. (Deutsche Reiterliche Vereinigung, 1999).

Incorrect riding position could have several different causes, such as poor strength and balance (Wilkinson and Graham, 2008) or poor standing posture. Weight distribution of the rider and thus the centre of gravity of the horse are affected by poor riding position (Schamberger, 2002). A common compensatory action of riders is gripping with the knees and thus stabilising the torso. The tense thighs cause the lower leg to be displaced posterior, ultimately aggravating a forward tilt of the torso (Dietze, 2003). This fault is commonly seen in riders with a lordotic spine, forward shoulders and anterior pelvic tilt. Riders with a kyphotic spine tend to lean backwards to achieve an upright position of the trunk. The pelvis is thus rotated posterior, causing the legs to drift forwards to obtain balance. Postural defects of the rider require the horse to counterbalance. Adapted movement patterns contribute to further postural imbalances in the rider and will also cause asymmetric muscle development and muscle wastage in the horse (Schamberger, 2002).

Aligned riding position requires the iliac crests to be of even height, with each *ischium* being connected to the saddle. This position facilitates aligned spine, with no rotation throughout the spine from lumbar to cervical vertebrae (Stewart, 2004).

Janura *et al.* (2009) found that locomotion impulses, which stimulate postural reflexes, are transferred to the rider in walk. This was found to improve balance and coordination. Increased stability of the CoG was found in more experienced riders.

This is supported by Peham *et al.* (2009) who found that the more skillful rider had a positive influence on the consistency in movement of his horse.

Symes and Ellis (2009) investigated riding position finding asymmetry in the shoulder with a preferred axial rotation towards the left and thus blocking movement to the right. They believe that this may lead to injury because of spinal instability and suggest that an exercise programme promoting flexibility and core stability may reduce movement asymmetry. The finding of asymmetry in the rider is supported by research of Muenz *et al.* (2014) who found that most right handed beginners tend to flex their right hip more and thus showing increased pelvic tilt to the right. The more advanced rider stayed much closer to the mid position. Clayton (2013) explains the increased flexion of the right hip with diagonal dominance. Over activity and shortening of the right hip flexors cause an anteroventral tilt of the right ilium, an elevation of the right ischium and the posterior ilium. In right-handed people the left leg is often longer, more open and more dynamically stable than the right (Spry *et al*., 1993). Muenz *et al*. (2014), however, argue that it could also be caused by the downward pulling of the right pelvis by the right hip flexors. The reason for the mid-position of the advanced rider can be explained through increased balancing skill, but no explanation of the tendency towards the right, rather than the left, of the beginner can be given.

Nevison and Timmis (2013) investigated whether rider asymmetry and instability could be improved through physiotherapy intervention. Six riders were assessed for postural stability by sitting on a force plate for 30 seconds. The displacement of the Centre of Pressure was used as indicator for instability. Asymmetry was assessed via a pressure sensor mat on a saddle horse for 10 seconds. Three of the six riders received physiotherapy focusing on the muscles connecting the pelvis. Both measurements were taken pre and post intervention with less than 10 minutes between intervention and remeasurement. Before treatment there was no significant difference between the physiotherapy intervention and control groups. Five out of the six subjects showed higher pressure readings on the right side with the sixth subject having an even distribution of pressure. After treatment, the intervention group had significantly lower postural instability as well as even pressure distribution. No significant changes in peak and mean pressure as well as maximum force were recorded and the control group showed no changes in any of the parameters. This research shows that imbalances can at least temporarily be addressed by physiotherapy. Further research investigating the long term effects and other intervention methods are suggested, but it was suggested that physiotherapy and core training techniques for riders could be used to target the discrepancies in horse and rider health that were previously reported (Dyson, 2000; Nadeau, 2006; Quinn and Bird, 1996).

2.13 Pilates

Pilates is said to be a full body conditioning programme that focuses on training the mind and body to work together more effectively and efficiently (Massey, 2009). It aims to dramatically transform the person's aesthetics and performance (Jago *et al.*, 2006; Sekendiz *et al.*, 2007). Pilates incorporates modern exercise science and rehabilitation principles, emphasising neutral alignment, core stability and peripheral mobility (Emery *et al.*, 2010). Pilates exercise is based on the continuous activation of the main powerhouse muscle, the *transversus abdominis,* along with the internal and external oblique muscles that provide core stability (Mullhearn and George, 1999). Through increased core stability and control Pilates training claims to improve balance and thus affecting athletic performance positively (Anderson and Spector, 2000; Hutchinson *et al*., 1998; Segal *et al*., 2004). Fitt *et al*. (1993) has found in a group of dancers that Pilates mat exercises have an advancing effect on static and postural balance.

Pilates aims to elongate and tone muscles without hypertrophic strength gains that traditional resistance exercise results in. Pilates emphasises proprioception, body awareness and correct posture in exercise prescription and whilst performing movements (Curnow *et al.*, 2008; Massey, 2009). Pilates has been shown to improve flexibility, agility and economy of motion thus being advocated for athletes and health alike (Kibler *et al.*, 2006; Curnow *et al.*, 2008). The low impact nature of Pilates makes it popular for use in low fitness level groups and in rehabilitation (La Touche *et al.*, 2008) and may be especially adequate to facilitate small enhancements of performance in athletes through small, controlled movements (Johnson *et al.*, 2007).

Through the upright posture while exercising muscle training of lower back and abdominal core is encouraged which suggests that the torso is stabilised and the whole body can move freely and independently whilst maintaining optimal pelvic position and posture (Argo, 1999). It must be noted that in a short-term training programme abdominal muscle strength is trained more than lower back musculature (Sekendiz *et al.*, 2007). Core muscles are not subject to training for speed or force, but emphasis on the stabilisation of the spinal column and pelvis (Lawrence, 2007). Because of the great emphasis that is placed on neutral alignment during exercise symmetry of the body is restored. Overtrained muscles are corrected and weak muscles strengthened (Muscolino and Cipriani, 2004). It can be hypothesised that this is unlikely to be achieved on horseback, where rider and horse continuously compensate for each other's postural misalignments. Therefore, bad habits should be approached from the ground.

Sekendiz *et al.* (2007) found that Pilates exercise improved trunk flexibility. Since flexibility is an important prerequisite for a deep seat and good riding performance it can by hypothesised, that Pilates exercise may improve rider position. Improved muscle endurance was also observed (Sekendiz *et al.*, 2007). A study on skeletal muscle in mice by Salminen and Vihko (2008) suggests that muscle endurance may decrease the risk of injury caused by cell damage.

Pilates focuses on whole body movements and isolated exercises meaning that large muscle group and specific muscle neuromuscular pathways are targeted depending on the exercise prescription and aim of the programme (Muscolino and Cipriani, 2004). The Pilates system advocates developing the correct neuromuscular pathways before the overload training principle is integrated (Curnow *et al.*, 2009). Herein emphasis is placed on controlled use of eccentric, concentric and isometric muscle contractions (Massey, 2009). Developing correct technique means that Pilates is invaluable for injury recovery, sports performance, good posture and optimal health (Akuthota and Nadler, 2004).

In Pilates movement is aimed to occur free of tension (Massey, 2009). Focusing on breathing promotes attention and awareness. Lateral costal breathing is beneficial for relaxation and focus. It can be achieved when inhaling at the point of effort (Muscolino and Cipriani, 2004). Thoracic control and use of the lower ribs are increased. The connection between pelvic floor and the diaphragm is enhanced, through activation of the *rectus abdominis* and breathing deeply into the ribs at the same time (Massey, 2009). Lack of oxygen supply to muscle can be a source of pain and injury (McGill *et al.*, 2000). Increased oxygen supply to the muscle is thought to enhance muscle relaxation (McGrath *et al.*, 2008).

In recent years, a range of movements, have started to promote Pilates exercise as beneficial to horse riding performance including Equestrian Pilates, Equipilates, Equilates, RiderPilates, etc. which are available to be taught by a variety of instructors. Some research has been carried out investigating the effect of Pilates exercise on horse riding position with the general consensus being that riding position is improved through Pilates exercise. Boden and Randle (2012) found that a rider specific exercise programme based on Pilates exercise resulted in a position closer to the vertical and Sudhoff (2010) found that through improved flexibility lower leg position was closer to the vertical after an 8 week Pilates exercise programme.

2.14 Fitness Testing

Athletic performance, amongst others, is related to physiological, biomechanical and psychological factors. The most effective way of preparing for competition is based on proven scientific principles, rather than trial and error. The same training method on a group of athletes will not cause the same response for all of them, due to everyone adapting to training differently. Training for elite performance is demanding, stressful and may create health problems, with many athletes not ensuring they are healthy. Fitness testing may reveal abnormalities that may not be detected during standard physical examinations. Testing can be an educational process for the athlete, where he or she learns about their body and the demands of the sport. Fitness testing will, however, not identify potential talent, determining genetic limitations and some tests, such as muscle biopsies, are questionable in their efficiency as well as reliability (Brown, 2001). To effectively test for fitness the variables tested need to be relevant to the sport as well as the phase of training. Tests also need to be valid and reliable, meaning that they measure what they set out to. Protocols should be specific for what aspect of fitness is being tested as well as the discipline. For example, a cyclist would use a cycle ergometer, a runner a treadmill and a swimmer a pool, tethered swim or flume. To date no fitness test has been developed that takes place on the horse, which is why both the treadmill (Meyers and Stirling, 2000; Meyers 2006) and the cycle ergometer (Westerling, 1983; Devienne and Guezennec, 2000; Douglas *et al.*, 2011) have been used to indicate maximal aerobic capacity in horse riders. The cycle ergometer was used because it simulates the seated position of horse riding, whereas the treadmill was justified because the high amount of upper and total body work that is required in horse riding cannot be imitated on the cycle ergometer. Oxygen consumption can be measured on the horse via a portable gas analyser; however, it would not predict VO^2max. It is therefore, to date, uncertain what the best way to test for maximal aerobic fitness would be.

Fitness testing should be standardised and ethical as well as repeated at regular intervals. The results then need to be interpreted by the athlete, coach and fitness expert. In the end the best measure of performance is performance itself. There are several reasons for conducting testing from providing baseline data forming to basis for exercise programming and indicating athletes' strength and weaknesses, over screening for disease to determining the ability for specific work tasks and minimising the risk of a training programme.

Cardiovascular fitness – Aerobic testing

The rationale for aerobic testing is based on the aerobic metabolism predominating in events that last more than two to three minutes. The oxygen comes in through the respiratory system and is passed on through the blood stream via the heart to the muscles. Increased aerobic capacity allows for increased ATM generation through either carbohydrates or fat. Athletes with a better aerobic capacity are expected to perform better through decreased fatigue. The maximal rate at which oxygen can be consumed is known as VO^2max. This can be detected as a plateau in oxygen consumption despite further increases in exercise intensity. The most accurate measure of VO^2max is via gas analysis, where the intensity of the protocol is gradually increased until the subject is exhausted. This is also known as direct or maximal aerobic tests.

Aerobic capacity can also be estimated through predictive tests such as Cooper, Balke, Multi Stage Fitness Test (Beep), Astrand, Rockport Walking Test or the Bruce Test. These tests are usually shorter and safer, particularly for high risk subjects. They are also inexpensive and require minimal equipment so that the athletes can even test themselves at home. Indirect tests can be carried out as a field test, which usually includes running a set distance, as well as a graded exercise test (GXT), which can be carried out in a lab on a treadmill, cycle ergometer or as bench stepping. The advantage of field tests are their quick and inexpensive nature, with disadvantages such as motivation and pacing skewing the results. They are useful for testing large groups, but not recommended for individuals as they are less accurate. GXT's are more reproducible, as the pace is set and accommodate the least to the most fit. They use a natural activity, with running yielding the most accurate results as it places the greatest load on the system. The disadvantage of the GXT's is the equipment, which is more expensive to source. Variables that are most commonly measured during a GXT are HR, Blood pressure, rating of Perceived exertion (RPE), eCG and blood lactate.

Flexibility testing

Flexibility assessment is an important part of health-related screening as compromised flexibility can affect daily living (American College of Sports Medicine, 2009). Identification of joints that have less flexibility than desired and asymmetries can be identified and prophylactic measures taken to prevent injury, trauma or movement pattern complications (Walker, 2011).

The gold standard to assessing flexibility is the laboratory test using a goniometer (American College of Sports Medicine, 2009). Considering the large number of joints in the body that need to be assessed this, however, is often not practical in real life or research setting. The most commonly used method of assessing flexibility is the sit-and-reach test in which several versions have been developed to cater for a wide range of users (Baltaci, 2003). These tests measure flexibility over many joints, so even with a good score there could be joints that have less than the desired amount of flexibility. Norms for all variations are also not well established (Heyward and Gibson, 2014).

For this study, the Flexitest by Claudio Gil Suarez de Araújo (2004) was used. The Flexitest provides a protocol for the joint specific testing of twenty joints with detailed instruction on how to perform and grade. With no equipment required this test is ideal for the field. Joint flexibility is tested in a passive way and scores between 0 and 4 are given for each of the joints tested. Flexibility of the hip, which is considered important in the rider, is measured by flexion, extension, abduction and adduction (Dietze, 2003; Araújo, 2004).

Balance testing

Traditionally, balance was measured by the length of time a subject can hold a certain position in equilibrium (Vrieling *et al.*, 2009), though these were originally designed to test for balance in those with neurological disorders. The unipedal static balance test is widely used (Balogun *et al.*, 1992; Hahn *et al.*, 1999; Riemann *et al.*, 1999a), but the relevance of static balance to the dynamic setting in the sporting disciplines is unknown. It is hypothesised that the static balance tests does not challenge the healthy athlete enough to elicit balance deficits (Riemann *et al.*, 1999b). Dynamic balance is not very well understood to date, but some measures of dynamic balance include functional performance tests such as using unstable surface to challenge balance, measuring balance during immediately after movement and the ability to stay stable whilst one part of the body performs a movement (Donahoe *et al.*, 1994; Brauer *et al.*, 1999; Riemann *et al.*, 1999b). Because of the dynamic setting of most sports, the validity of these tests could be questioned. Laboratory tests generally include force platforms, electromyography or motion analysis (Moe-Nilssen, 1998). These test measure dynamic balance, but their expensive nature is generally unsuitable for field conditions. Additionally, this equipment is normally non-portable and complicated. Dynamic balance is accepted to be complex in nature and no measurement tool would be appropriate for use across the board (Emery, 2003). Riding position is considered to be mainly a static exercise in a dynamic setting where the illusion of no movement is created. This lead to choosing a balance test that entailed maintaining a static position in a dynamic setting: the unipedal stance test on an air-filled balance cushion.

Core stability testing

There is no consensus on the definition of core stability and so measurement is difficult. Several tests, however, claim to measure the components of core stability including core strength, endurance, flexibility, motor control and function. Leetun *et al.* (2004) found that those with stronger core muscles were less likely to suffer injury suggesting that core strength could be a valid measure of core stability. The findings of LiLi (2012), on the other hand, found core endurance tests to be the most reliable measurement of core stability with strength tests only rated third after flexibility. The protocol that was followed for the endurance tests was developed by McGill *et al.*

(1999) and consisted of endurance testing of the trunk extensor, trunk flexor and bilateral side bridge tests.

Other core stability tests include functional movement tests, where difficulty to perform would indicate core stability impairment (Kibler *et al.*, 2006). These tests usually consist of squatting, planking or similar activities (Loudon *et al.*, 2002). Flexibility and Balance tests could also indicate core stability (Cachupe *et al.*, 2001; Gabbe *et al.*, 2004). It is suggested that the use of isolated tests would only give insight to part of the complex fitness component that is core stability (LiLi, 2012). In this study, the protocol by McGill *et al.* (1999) will be utilised as is believed to be the most specific to the demands of horse riding with both horse riding and the McGill protocol challenging core muscle endurance.

Postural assessment

Static postural assessment is used to indicate imbalances in posture that should be eliminated, because they could lead to injury or inhibit optimal performance (Massey, 2009). Visual observation of posture is one of the most common ways of assessing clients, but Singla and Vegar (2014) argue the only positive of this method is it does not require any equipment. Some of the negatives include that minor postural alterations cannot be picked up. Photo analysis through the aid of markers is another way of assessing posture. Markers can easily be misplaced or move on the subject after being put on. Larger distances won't suffer as much as small angles, but the misinterpretation of posture due to methodological difficulties can change the entire outcome of the study. It also still relies on visual observation. Photographic analysis of posture is relied upon heavily despite the disadvantages (Wojtys *et al.*, 2000;

Guimarães *et al.*, 2007; Grabara and Hadzik, 2009; Kilinc *et al.*, 2009; Rankin and Boeyer, 2011; Radaš and Bobic, 2011). Goniometers measure angles objectively, are considered to be of good reliability, but have been reported to be relatively difficult to use (Harrison *et al.*, 1996). The gold standard of postural analysis could be considered to be the radiographic method due to a high reliability. Contra point of this method is the exposure of the subjects to harmful radiation and its expensive nature (Singla and Vegar, 2014).

The postural assessment method that was used throughout the research conducted in association with this thesis is based on the visual observation in line with the New York Posture Rating Chart. This method has been accepted as a good field alternative to the more expensive laboratory testings (Hennessey and Watson, 1993; Panky and Woolsley, 2004; Womack et al., 2009).

2.15 Questionnaire design

When developing a questionnaire a number of things should be considered. These include the type of questionnaire, the subject group studied, the research questions that an answer is sought for, the type of questions that are asked, etc (Oppenheim, 1998). Any type of survey should be able to answer a question that was asked by the author. In addition to this, it should be specified which group of people should be asked the questions. In the case of the study contained in this thesis only horse riders were asked to participate in the survey, because the author was interested in the opinion of horse riders on a particular subject. If the questionnaire would have been open to the wider public most respondents would have likely either guessed answers or given up as they would not have been able to understand the context of the questions.

To be able to analyse the opinions of the subjects one should also consider asking a number of demographical questions, such as gender, age, income, or whatever may be appropriate for the research question asked. If previous studies have looked at similar questions it may be worth designing the questionnaire similarly for comparison. There are also several ways of asking questions. No question should be leading, which means that the respondent is led to answer in a certain way by the way the question is asked. If this was the case the result of the questionnaire should be considered void as the respondents could not be assumed to have answered the questionnaire truthfully out of their belief.

Questions can either be open ended or closed. Open ended questions invite the respondent to answer in their own words and whereas closed questions usually leave only the option of multiple choice. Open ended questions would result in greater depth and detail of the answer, but might be unsuitable for large populations. If one word answers are given this would also make it much harder for whoever analysis the questions to group for analysis. Closed questions would be much easier to use in big sample sizes, but do not leave the option for regrouping as no greater detail is known (Oppenheim, 1998).

When the questionnaire has been developed it needs to be tested on a suitable sample via a Pilot study. This aims to highlight any issues in the way questions are asked, the understandability or possible problems with the answering of the research question.

The way the questionnaire is distributed should also be considered. Online questionnaires are easier to distribute, but are generally random. Postal questionnaire depend on a higher motivation of the respondent to post back the results as opposed to just filling it out online. Women have been found to be more likely to partake in questionnaires than men (Jackson *et al.*, 2001).

The most well known survey of equestrian interest is the National Equestrian Survey (2010/11) that has been developed and analysed by the British Equestrian Trade Association (BETA). The main interest of this survey was to investigate the types of people involved in horse riding, the trade value of the equestrian industry and related issues. The BETA survey had a large number of young respondents with 25% of respondents being under 16 years, 23% being 16 to 24 years, 32% being 25 to 44 years and only 20% being 45 years or older. The main area of geographic location was the South East at 36% followed by Wales/South West and the North East at 17%

and the Midlands at 16% Scotland and the North West were only represented at 6% and 8% respectively. BETA also found that half of the respondents keep their horses on their own land. Considering this it could be argued whether or not this sample is a representative of the equine industry in the UK.

2.16 Aims of the research

The aim of the following research was

1) to investigate the perceived importance of off-horse exercise for riding position.
2) to explore the impact of certain fitness parameters including balance, core strength, flexibility and cardiovascular fitness on riding position.
3) to test the effectiveness of a specific fitness programme to improve riding position.

Chapter 3

Materials and Methods

3.1 Introduction

The increasing demand in sports science as a way to improve performance across the disciplines calls for horse riding to adapt to the times and also look to science for solutions. Few studies on the demands of horse riding have been published with none to the author's knowledge on the influence of fitness on riding position. The relatively new field of equitation science leaves the need for new methodologies to be developed to test for rider specific fitness. This study has adapted previous methodologies from horse riding and other disciplines to establish a way of conducting research that is as useful as possible.

3.2 Questionnaire study

Having discussed the possibilities of fitness parameters to be of positive influence to riding position and human and equine welfare it was of interest to investigate the views of the equestrian population in this matter. The survey included questions investigating general demographics, riding habits and the respondent's view on the importance of off-horse exercise on horse riding. This was done to establish the standing of off-horse exercise within the industry, the demand as well as those most likely to participate.

Survey design

The questionnaire was designed for a quantitative data collection. A large number of respondents were anticipated, so that a closed format was used for the majority of questions to achieve answers within give categories and avoid having to guess which category a particular open answer would have to be classed in (Oppenheim, 1998).

Those answers that were expected not to be straight forward also had an available "Other" answer possibility in which case the respondents were asked to specify. The questions were formulated in a way, that no right or wrong answer could be assumed by the respondent to avoid leading questions; however, the survey could have been named a less leading title as answers could possibly be influenced by the respondent knowing the nature of the questionnaire (Oppenheim, 1998). Data such as age and years of riding experience were collected in exact measures (years). Exact measures were recorded to allow for re-categorising in the event of too little respondents in any given category or also to be able to establish sub-categories if wanted. The questionnaire was hosted on the cloud-based service "Google Drive" (https://drive.google.com). The introduction was formulated in a way that the respondents had all necessary information prior to participating in the study. The respondents were assumed to have given informed consent if they went ahead with the survey. The questionnaire was piloted on students of three different classes, with 21, 25 and 28 students per class, pre-publication to eliminate any lack of clarity in the way the questions were asked. Changes were made mainly to the format of questions changing them from open to closed format questions and adding options for some of the multiple-choice questions. The Writtle College Ethics Committee was then consulted and granted approval.

The first section of the questionnaire was focusing on the general demographics of the respondents, such as gender, age, annual income, geographical location, etc. This questionnaire was designed mainly for the UK horse rider, but there was no restriction due to geographical location. For comparison purposes this section was closely linked to the 2011 national Equestrian Survey of the British Equestrian Trade Association.

Following on were questions investigating the respondents' riding habits, such as their riding experience, main discipline, riding tuition, willingness in risk taking, competition habits, etc. The final section looked at the off-horse exercise habits of the respondents, which included the nature and frequency of secondary exercise habits as well as the perceived importance of off-horse exercise on riding position. The complete survey has been made available to view in Appendix 2.

Survey distribution

Distribution channels were mostly Facebook groups that were aimed at horse riders across the country and link shares through friends and colleagues. The link to the "Google Drive" site hosting the questionnaire was also sent off to contacts within BEF and the international society for equitation sciences (ISES) and was distributed via e-mail, networking sites, such as Facebook and Twitter to members from there. The online survey was chosen, because a large amount of people of the horse-riding category could be reached within a short period of time, though the distribution of demographics in this particular method of distribution could not be influenced. It was to be expected that the majority of respondents would be female, as women have been found to partake in horse riding (Dashper, 2013) and more likely to participate in online surveys (Jackson *et al.*, 2001) and from a South East geographical location as that is where the author has most connections and the link was likely to be most widely spread.

Survey analysis

The questionnaire was online and available for response for four months between 09/04/2013 and 10/08/2013. Data was automatically collected in Excel format

(Microsoft Corporation, Redmond, WA) on the Google drive and downloaded at the closing of the questionnaire. The data was then transferred to IBM SPSS Statistics version 21 (IBM Corporation, Armonk, NY) for analysis. Some of the data was collected in exact measures so this had to be put in categories for the analysis, i.e. the questionnaire asked for the exact age and amount of years the respondents had been riding. The way the data was categorised for this was closely linked with the categories used in the National Equestrian Survey (2011) by BETA. Descriptives were generated in SPSS and the tables and figures were produced with Excel. A Pearson Chi-Squared test (χ^2) was used to check for associations between the respondents' demographics, riding habits and perceived importance of off-horse exercise. The 5% significance level ($P<0.05$) was used. The frequency of some groups was insufficient to examine every relationship because of which some data needed to be grouped where appropriate.

3.3 Riding position

Before any of the research for this commences both studies were granted approval by the Writtle College Ethics Committee.

Gender differences in the pelvis, with females having a wider pelvic girdle and a greater pubic angle were the reason for only using female subjects in these studies (Gray, 1987). Apart from this reason they are also more widely available as a greater percentage of horse riders are female (Dashper, 2013) and it would have been difficult to recruit enough male subjects to make any significant statistical comparison between genders (Landau and Everitt, 2003). Any age range was included in the study as long as they were 18 years old and above for child protection reasons (NSPCC, 2014). Recruitment was random and anyone who rode at least one hour in an average week was invited to take part. Advertisement was mainly done through presentation in lectures at the college as well as “Facebook” campaigns on various pages, such as “Essex Horse Riders” and word of mouth promotion. The author also wrote an article about fitness and horse riding that was published in the *Essex Rider* - a local magazine for horse enthusiasts – inviting the readers to be part in the cross-sectional study on the impact of general fitness parameters on riding position. Emails were also sent out through the local riding club “Ingatestone and Blackmore riding club” with invitations to their members. Anyone who was interested would contact the author and would be provided with a detailed description of the respective research trial and the requirements that were asked of the participant and could then decide whether they would want to take part. Participants could at any point decide to end their cooperation. Before the testing commenced the participants were asked to truthfully complete a physical activity readiness questionnaire (PAR-Q) to establish that they were in good health and taking part in the study would not harm them (American College of Sports Medicine, 2010). Signing of a consent form was also required. The participants also filled in a short questionnaire mainly indicating their age, riding experience as well as habits (such as frequency, discipline, tuition, etc.) and other physical activity.

The dress code that was required for the study consisted of dark jodhpurs or leggings, a dark and fitted shirt and horse riding appropriate footwear. It was left at the discretion of the participants whether they wanted to wear full length riding boots or jodhpur boots, but they were advised to wear that, which they usually also wear when riding real horses. The reason for the dark clothing was that the skin markers that were used to establish the location of the anatomical landmarks were white (2.5cm diameter). This was to make sure, that the light markers would be seen on the video in the biomechanical software. This size of 2.5cm diameter, which is large for this type of biomechanical analysis was chosen because any smaller markers would not have been able to be seen in the video for analysis. Measurements were always taken from the middle of the marker; however, analysis could have been more accurate if the markers had been smaller.

The circular skin markers (2.5cm diameter) were placed on the anatomical landmarks, so that the analysis of angles from the video would be as accurate as possible and their location would not have to be guessed retrospectively. This was always carried out by the author to avoid inter-observer differences. The ankle (lateral *malleolus*); the knee (lateral side of the centre of the flat portion of the *condyles* of the femur); the hip (lateral *iliac crest* as well as *greater trochanter* of the femur); the shoulder (*acromion* process of the *glenohumeral* joint centre); and the head (*orbitale*) (adapted from Lovett *et al.*, 2004) were the anatomical landmarks that were used of the left side of each rider. The angular measurements that were used in the studies are adapted from the investigation on riding position by Lovett *et al.* (2004) and are defined in Table 3.1 and partly visualised in Figure 3.1 below.

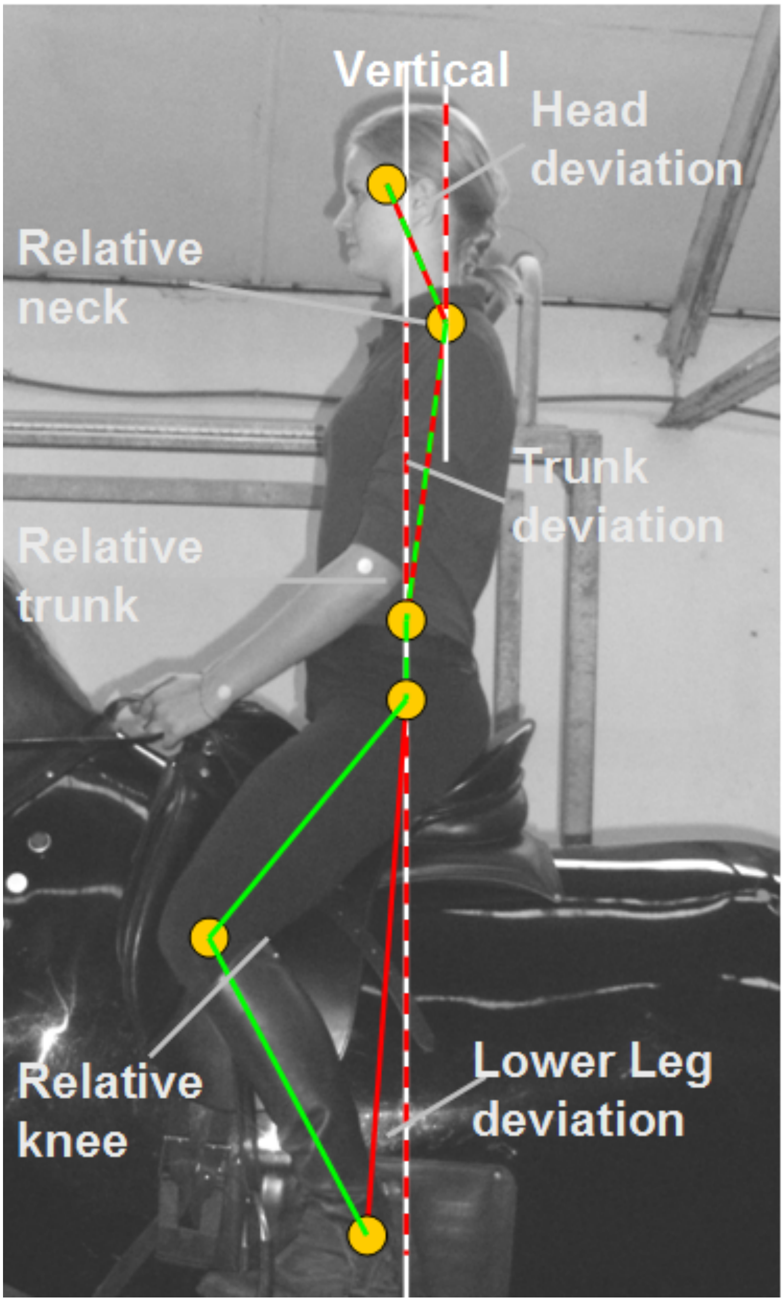

Figure 3.1: Visualisation of the angles measured in riding position minus hip deviation which was the angle that was formed by the lateral iliac crest, the *greater trochanter* and the vertical. (*Source*: The author, 2015)

Table 3.1: Definition of the angles measured during the study.

Description of Angle	Geographic landmarks involved	Angle measured
Relative knee	• lateral *malleolus* • lateral side of the centre of the flat portion of the *condyles* of the *femur* • greater *trochanter* of the *femur*	Obtuse angle
Relative trunk	• lateral side of the centre of the flat portion of the *condyles* of the *femur* • lateral *iliac crest* • *acromion* process of the *glenohumeral* joint centre	Obtuse angle
Relative neck	• lateral *iliac crest* • *acromion* process of the *glenohumeral* joint centre • *orbitale*	Obtuse angle
Lower leg deviation	• lateral *malleolus* • lateral side of the centre of the flat portion of the *condyles* of the *femur* • vertical	Absolute angle (positive or negative deviation from the vertical)
Trunk deviation	• lateral side of the centre of the flat portion of the *condyles* of the *femur* • *acromion* process of the *glenohumeral* joint centre • vertical	Absolute angle (positive or negative deviation from the vertical)
Head deviation	• acromion process of the *glenohumeral* joint centre • *orbitale* • vertical	Absolute angle (positive or negative deviation from the vertical)
Hip deviation	• lateral side of the centre of the flat portion of the *condyles* of the *femur* • greater *trochanter* of the *femur* • *vertical*	Absolute angle (positive or negative deviation from the vertical)
Total deviation	• Sum of Lower leg, trunk and head deviations.	

Reliability of marker placement

A small study (n=3) examined the consistency of marker placement. Skin markers were placed on the six anatomical landmarks mentioned previously, of three individuals and the distance between markers as well as the distance between each marker and the floor was measured with a tape measure and while standing. Measuring these distances whilst seated on the horse may have been more indicative of repeatability; however, the rider would have been too tall on the horse for the tester to measure accurately. The tape measure approach was chosen because the Biomechanics Software was used for angular analysis, which was irrelevant in standing position. Because of the large size of the markers this approach was also likely to be more accurate. To test intra-rater reliability the markers were placed on the subjects again on another day and re-measured by the same person. The Intraclass Correlation Coefficients (ICC) with the two-way mixed model for absolute agreement as calculated by SPSS was used and Cronbach's alpha results are displayed in Table 3.2.

Table 3.2: Cronbach's Alpha for the Intraclass Correlation Coefficient statistical results for marker placement reliability (n=3).

Description	**Cronbach's Alpha**
Floor to head	.975
Floor to shoulder	.978
Floor to hip	.996
Floor to greater *trochanter*	.810
Floor to knee	.975
Floor to ankle	.923
Head to shoulder	.935
Shoulder to hip	.965
Hip to greater *trochanter*	.808
Greater *trochanter* to knee	.833
Knee to ankle	.828

Riding position data collection

The subjects were asked to ride the mechanical horse as they would ride an actual horse in walk, trot and canter. Participants were given a brief period of time to adapt to the movements of the mechanical horse, which related to the time from starting the mechanical horse to the researcher walking across the room and beginning the recording. The gaits of the mechanical horse that were used were the fast walk, fast trot and fast canter. Although GRF forces in walk are too low to observe a change in position due to core stability training (Clayton, 2004), all gaits were recorded in case other fitness parameters would make a difference.

Video clips were recorded on a frame-by-frame basis over four consecutive stride cycles in each gait at a frequency of 50 frames per second. The camera (Canon, MD150, Tokyo, Japan) was set up perpendicular to and at a distance of six meters of the mechanical horse, to allow for the whole body of the rider to be visible on the recordings (Figure 3.2). The known distance of the base of the mechanical horse was used for calibration purposes.

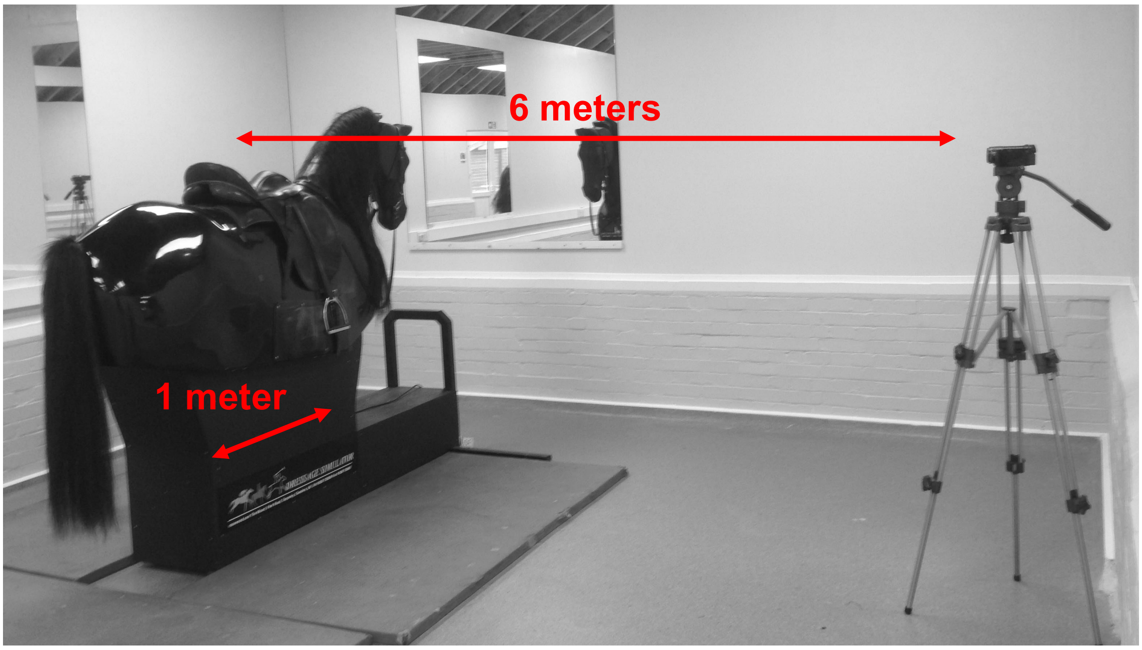

Figure 3.2: Research set up with the known distance of one meter for calibration.
(*Source*: The author, 2015)

The recordings were imported in to the Quintic Biomechanics Software v.19 (Sutton, United Kingdom) with which rider position was analysed via manually tracking the markers. Manual tracking was chosen, because the lighting conditions at the location where the mechanical horse was stationed would not allow for automatic tracking. Automatic tracking with good light and contrast between markers and subject is likely to be more reproducible as it uses the pattern to pick the same spot each time. It also works much quicker. Unfortunately a lot of manual correction is necessary when lighting conditions are poor, therefore making it as time consuming as manual tracking, if not more so. The angular measurements were calculated by the software and could then be exported into Excel (Microsoft Corporation, Redmond, WA). The way the data was then analysed varied between studies and is described in detail below.

Cross sectional study

For the cross-sectional study only one frame per stride was analysed. This was done over four consecutive strides at the same point of the stride cycle. In this study, the point at which the point of hip of the mechanical horse was at its lowest was used in all three gaits. The mean of the four strides was then used from each angle to establish riding position as well as their relation to fitness parameters.

Intervention study

After the experience from the cross-sectional study in this experiment, riding position was analysed slightly different from before. The angles all stayed the same, but for this trial all frames for the four consecutive stride cycles were analysed. This method was chosen as the stride cycle could be looked at as a whole and the Range of Motion (ROM) of the angles could be established. This was achieved by finding the biggest and smallest angle and subtracting the minimum from the maximum for all four strides. The mean of the four strides was then used. By using this method conclusions could be drawn as to the amount of movement a particular rider displayed during a stride cycle in any of the given gaits. For the angles of riding position in this study the mean angle of the ¾ point of the stride cycle was used for analysis. This point was chosen because the stride cycle was started with the lowest point of the croup of the mechanical horse. This point is known in the stride cycle to have a high amount of GRF's acting on the rider. The same would be true for the ½ point in the stride, which is why the middle of the two was chosen. This point was found by multiplying the total number of frames per stride by ¾ and then using the data of the frame that was closest to the result. If for example the total number of frames in trot on the mechanical horse was 17 frames the calculation would be as follows: 17 * ¾ = 12.75 and therefore the data of frame 13 was used, because it was assumed to establish the same point in the stride cycle.

Mechanical horse validation study

To validate the mechanical horse for the use in this research a short study was designed to investigate the differences of riding position on the mechanical horse as opposed to the real horse. Three riders were recruited to ride the mechanical horse in walk, trot and canter as well as a real horse in walk, trot and canter. Three different horses in type and conformation were used. This was to give greater chance of representing the diversity of the equine population compared to the mechanical horse.

The set up with the real horse was similar to that of the mechanical horse. The camera was positioned parallel to the edge of the riding arena covering an area of 5m to allow for one whole stride to be recorded. Each rider had to ride past the camera three times per gait to ensure that three strides in each gait were recorded for comparison. A stride was measured from the horse's point of croup being at its lowest point within the stride cycle to the next time it arrived at this position, just as it was measured with the mechanical horse. The known distance that was used for calibration was the length of the saddle pad of each horse to ensure that the measurement was in the same plane as the rider.

To ensure the same conditions for the riders, stirrup length was standardised by measuring the length on the top of the stirrup leather to the bottom of the stirrup iron on the real horse and then ensuring the same length was used on the mechanical horse.

The data was again analysed in Quintic and the results then exported to Excel. The low number of data points resulted in non-parametric data; therefore, the Wilcoxon signed rank test was used to compare data. Using the 95% significance level no significant differences between angles were found at the ¾ point of the stride as well as ROM in all three gaits (Descriptive and statistical analysis output are shown in Tables 3.3, 3.4 and 3.5).

Table 3.3: Mean and standard deviation of the riding position angles and ROM of those angles measured on the mechanical and real horse in walk and their Wilcoxon signed rank test results (n=3)

	Mechanical horse	Real horse	Z	Asymp. Sig.
Riding position				
Relative neck angle	168.88 ± 4.20	169.09 ± 7.01	-.535	.593
Relative trunk angle	154.71 ± 4.02	136.78 ± 2.77	-1.604	.109
Relative knee angle	134.38 ± 4.94	104.25 ± 6.17	-1.604	.109
Head deviation	9.46 ± 1.30	7.88 ± 3.35	-1.069	.285
Trunk deviation	1.06 ± 4.93	-1.74 ± 3.74	-1.604	.109
Lower leg deviation	4.43 ± 2.15	4.73 ± 2.72	.000	1.000
Hip deviation	6.92 ± 10.55	.19 ± 3.15	-1.069	.285
ROM				
Relative neck angle	11.00 ± 1.20	24.95 ± 2.08	-1.604	.109
Relative trunk angle	9.44 ± 1.18	22.66 ± 5.15	-1.604	.109
Relative knee angle	4.98 ± 74	15.53 ± 1.80	-1.604	.109
Head deviation	7.13 ± 1.06	14.36 ± 2.34	-1.604	.109
Trunk deviation	7.34 ± .69	12.45 ± 2.38	-1.604	.109
Lower leg deviation	1.99 ± .55	10.22 ± 2.14	-1.604	.109
Hip deviation	14.51 ± 3.89	19.53 ± 2.08	-1.604	.109

Table 3.4: Mean and standard deviation of the riding position angles and ROM of those angles measured on the mechanical and real horse in trot and their Wilcoxon signed rank test results (n=3)

	Mechanical horse	**Real horse**	**Z**	**Asymp. Sig.**
Riding position				
Relative neck angle	165.92 ± 7.14	178.93 ± 7.75	-1.604	.109
Relative trunk angle	155.16 ± 3.85	127.96 ± 7.75	-1.604	.109
Relative knee angle	136.48 ± 8.44	112.10 ± 6.78	-1.604	.109
Head deviation	12.58 ± 4.94	5.08 ± 2.11	-1.604	.109
Trunk deviation	2.03 ± 2.77	3.51 ± 5.91	-.535	.593
Lower leg deviation	4.76 ± 2.43	11.35 ± .57	-1.604	.109
Hip deviation	6.78 ± 9.29	1.60 ± 4.37	-.535	.593
ROM				
Relative neck angle	15.21 ± .99	21.34 ± 3.19	-1.604	.109
Relative trunk angle	12.18 ± 2.36	16.92 ± 3.24	-1.604	.109
Relative knee angle	5.98 ± 2.86	15.31 ± 2.81	-1.604	.109
Head deviation	7.02 ± .32	14.84 ± 2.91	-1.604	.109
Trunk deviation	10.16 ± .12	9.88 ± 2.44	.000	1.000
Lower leg deviation	2.49 ± .79	8.59 ± 1.81	-1.604	.109
Hip deviation	14.85 ± 1.76	20.57 ± 6.93	-1.069	.285

Table 3.5: Mean and standard deviation of the riding position angles and ROM of those angles measured on the mechanical and real horse in canter and their Wilcoxon signed rank test results (n=3)

	Mechanical horse	Real horse	Z	Asymp. Sig.
Riding position				
Relative neck angle	164.86 ± 5.49	188.30 ± 1.80	-1.604	.109
Relative trunk angle	153.37 ± 3.23	128.98 ± 4.49	-1.604	.109
Relative knee angle	132.21 ± 8.23	113.94 ± 7.13	-1.604	.109
Head deviation	11.03 ± 3.80	6.08 ± 1.98	-1.604	.109
Trunk deviation	-5.12 ± 2.15	6.67 ± 6.19	-1.604	.109
Lower leg deviation	6.91 ± 2.63	8.97 ± 2.19	-1.604	.109
Hip deviation	4.80 ± 12.73	.18 ± 7.36	-.535	.593
ROM				
Relative neck angle	20.77 ± 3.45	26.72 ± 4.12	-1.069	.285
Relative trunk angle	25.96 ± 3.60	20.50 ± .63	-1.604	.109
Relative knee angle	7.43 ± 1.13	15.77 ± 4.40	-1.604	.109
Head deviation	7.49 ± 2.25	15.01 ± 2.30	-1.604	.109
Trunk deviation	16.39 ± 1.45	15.66 ± 3.37	.000	1.000
Lower leg deviation	10.12 ± .50	10.11 ± .96	.000	1.000
Hip deviation	17.69 ± 3.32	22.04 ± 4.11	-1.069	.285

It could therefore be assumed that riding position was not significantly different between riding a real horse and the mechanical horse and the mechanical horse can be used as a valid tool to analyse riding position allowing for standardised research practice that is not questionable regarding horse welfare.

3.4 Fitness parameters

While every care was taken to assure that the fitness tests used would be relevant to the horse rider it should be said that currently there are no protocols on how to establish fitness in horse riders. The following tests have been chosen to be feasible within the opportunities of the equipment available to Writtle College, while also being safe for a wide range of respondents as well as being within the limits of the small research set-up of these studies.

Balance

To measure balance the participants were asked to perform the Standing Stork Test on a Core Disk Stability Air Cushion (GoFit LLC, Tulsa, OK). For this the participants were asked to stand on the stability disk without shoes on one leg with the other leg raised off the floor until the suspended foot is at the approximate height of the other knee. Both arms were by the side of the body. When the respondent lost balance, which would have been indicated either by placing the suspended foot back onto the ground or by excessive movement of the arms the time would be taken (Schell and Leelarthaepin, 1994). The time (in seconds) was used as the indicator for the balancing ability of the subjects. The stability disk was included in the balance test to ensure that the reading would be representative of dynamic balance, rather than just standing balance (McCurdy and Langford, 2006). Subjects were given the opportunity to acclimatise themselves to balancing on the stability disk with the fourth attempt being the one that was recorded. Both left and right leg balance times were recorded.

Core stability

The three muscle endurance tests by McGill (2007) measuring, flexor, extensor and oblique endurance were chosen as the indicator for core stability within this study. It should be noted that core strength and core stability should not be classified as the same thing because core stability includes other variables apart from core strength, such as proprioceptive control, power and endurance and classifies the torso's ability to maintain good posture and balance especially during movement (Kibler *et al.*, 2006). Core strength has, however, been found to increase in line with core stability and thus identified as an indicator of core stability (Wilkinson and Graham, 2008). The tests by McGill were chosen because of the possibility to distinguish between flexor, extensor and oblique strength, which would also show asymmetries in core strength. The tests were also suitable to the field conditions in which the testing was carried out without the need for any equipment. Subjects were not encouraged during the testing and were informed of their times after each testing period. Trunk extension endurance was measured with the subject lying prone on a table with the upper body from the anterior superior iliac crest being suspended over the edge and with extended arms resting her weight onto a chair directly underneath her shoulders. The tester then held the subject's legs down to allow the subject to let go of the chair and fold her arms across their chest. In this position, the subject had her trunk suspended in the air with each hand resting on the opposite shoulder. When the subject let go of the chair the time was taken with a stopwatch until the subject was no longer able to sustain the horizontal position (Reiman *et al.*, 2012) (Figure 3.3 B).

Trunk endurance was measured with the subjects seated on a yoga mat with their knees flexed at a 90º angle and both feet on the floor in front of them. The subject was timed for how long she could sustain the position of a lent back trunk at a 45º angle to the floor behind her and with her arms crossed in front of her touching the opposite shoulders (Reiman *et al.*, 2012) (Figure 3.3 A).

Oblique endurance was measured using the side bridge. In this position, the subject was timed while she would be supported only on her lower arm from elbow through to wrist and the side of her bottom leg. The body was in a straight line with the head not leaning forward or the body twisting. If the hip would drop the subject would be asked to raise it back to achieve a straight body until she would no longer be able to sustain this position in which case the time was taken. This test was performed on both the left and right side (McGill, 2007) (Figure 3.3 C).

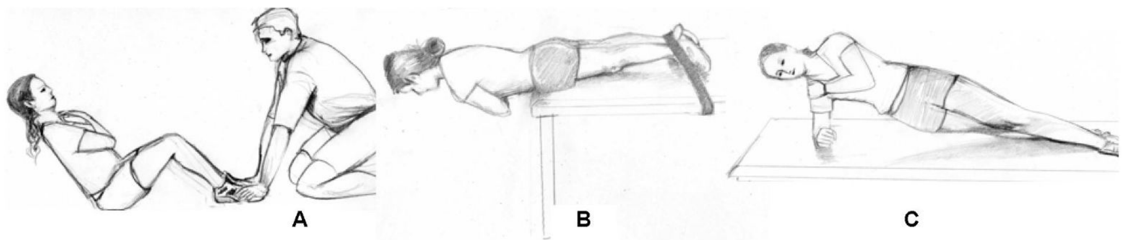

Figure 3.3: Positions for the endurance tests. A: Trunk flexors; B: Trunk extensors; C: Lateral. (*Source:* Nikolaidis, 2010)

Between testings the subjects were allowed to rest for a few minutes, until they felt they were ready to continue. If at any stage the execution of the tests was compromised the subjects were asked to alter their position. All subjects were specifically asked to cease maintaining these positions if they felt any discomfort apart from the normal burning sensation of muscle usage.

Flexibility

To measure flexibility the detailed protocol of Claudio Gil Soares de Araújo's (2004) Flexitest was adapted. This test comprises of 20 individual joint flexibility measurements which are explained in great detail in the book "Flexitest: an innovative flexibility assessment method". Flexibility of the wrist and elbow were disregarded for this study and thus only 16 tests were performed on the participants. Flexi test measures passive mobility so the author, who tested all subjects to allow for consistency, would put the subjects into a number of positions and then scored the flexibility on the basis of the final position that was comfortably reached by the subjects. This test was chosen because flexibility of the individual joints was recorded as opposed to other tests, such as the sit and reach test, in which the flexibility of several joints is measured at the same time and no distinction can be made (American College of Sports Medicine, 2010). This test was chosen over a goniometer because of the difficulty placing the goniometer properly. When hip flexibility is mentioned this refers to the sum of the scores that measure flexibility of the region around the hip including flexion, extension, adduction and abduction. An example of the instructions on how to measure flexibility according to the Flexitest is shown in Figure 3.4 below.

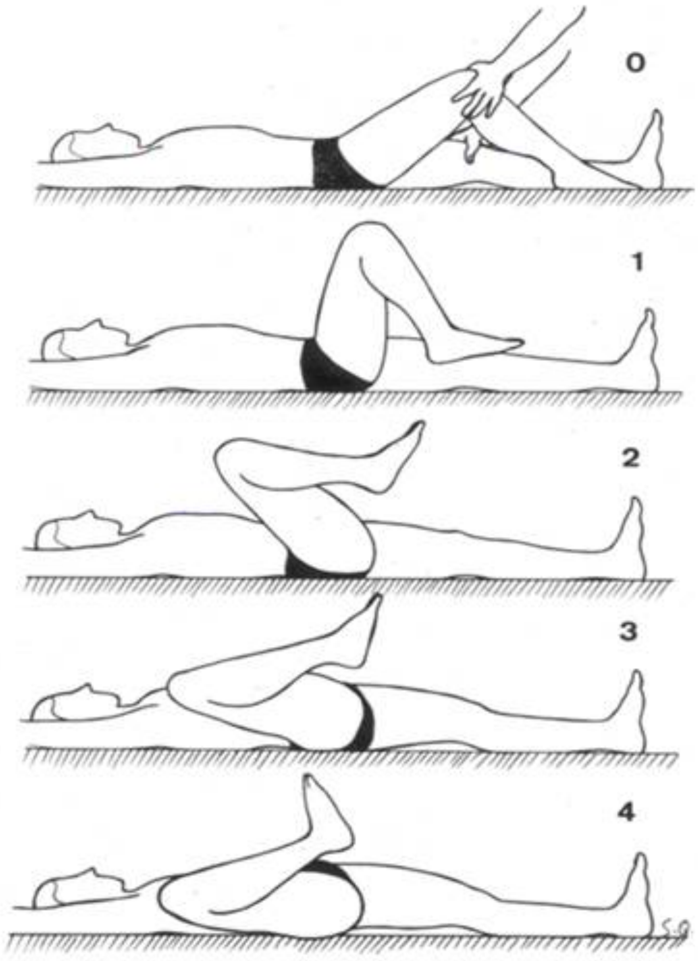

Figure 3.4: Flexitest measuring guide for hip flexion. The participant would be put into this position by the author and would receive the flexibility score that would resemble this guide most closely. (*Source*: Araújo, 2004).

Cardiovascular fitness

Cardiovascular fitness was established using the sub maximal cycle ergometer prediction test by Astrand Rhyming. A sub maximal test was used because all subjects had further fitness tests to partake in afterwards and state of fitness of the subjects was unknown and it was therefore considered safer in a field environment. Heart rate was measured using a heart rate sensor and training watch (Polar Electro, 2016). Aerobic fitness in horse riders would in an ideal situation be tested on the horse with the help of a portable gas analysis backpack; however, these resources were not available for this study and could therefore not be used. A seated test on the cycle ergometer was used instead. The difference between the cycling and horse riding would be that the leg muscles in cycling are used to produce force (eccentric and concentric contraction) unlike in riding where isometric muscle contraction is used to maintain stability on the horse. The advantages and disadvantages of this protocol were previously discussed in Chapter 3. The subjects were asked to warm up on the bike with no added weight. When the test started, the subjects were asked to cycle at a constant speed of 50W. The first two minutes the subjects would be cycling at a work rate of 300kg/m/min. After the two minutes the work rate would be increased to 450kg/m/min and after another two minutes to 600kg/m/min as is standard procedure. At the end of the six minutes the heart rate of the subject would be taken and together with their body weight their estimated VO^2max would be calculated using a nomogram by Astrand-Rhyming (1954). This test was used because it is a safe way of acquiring estimated aerobic capacity in a variety of subjects including those that may not be very fit. All subjects HR was below 135 bpm at the point at which HR was taken.

Though there is no trialled and tested measurement for aerobic capacity on the horse the subjects were asked to stay in the light seat in trot for three minutes. Heart rate was measured at the end to have an estimate of how cardiovascular fitness translated from off the horse to mounted. Technical difficulties prevented the collection of cardiovascular data for the second half of the cross-sectional trial. Having found in the cross-sectional study that cardiovascular fitness on the exercise bike was not related to an increased heart rate on the mechanical horse, this was excluded for the intervention trial.

Posture

Anterior, posterior and lateral posture photos were taken pre and post intervention (Canon, Powershot P5, Tokyo, Japan) (Figure 3.5). The photos were then retrospectively analysed, with a posture grid, by the author with the help of physiotherapist and Pilates instructor. Inter-rater reliability was high with scores for a large number of areas being identical and therefore giving a Cronbach's alpha of 1 (Table 3.6). Areas such as feet and arch in sagittal view and chest, upper back and neck did show greater variability between testers but these were still fairly reliable. In the end for these individuals where a disagreement was encountered in these areas these were dealt with by discussing and then agreeing on a score both testers considered appropriate.

Table 3.6: Interrater reliability analysis results (n=11).

Description	Cronbach's Alpha
Head (saggital)	1
Shoulders (saggital)	1
Spine (saggital)	1
Hip (saggital)	1
Feet (saggital)	.894
Arches (saggital)	.703
Neck (frontal)	.955
Chest (frontal)	.938
Shoulders (frontal)	1
Upper back (frontal)	.938
Trunk (frontal)	1
Abdomen (frontal)	1
Lower back (frontal)	1

Photos were assessed randomly so it was not obvious for the assessors at the time whether the photos were taken before or after the trial to avoid bias and ensure a degree of blinding. For postural analysis, the New York Posture rating chart was used. Again, posture was scored on a basis on which trait the subject was most exhibiting and the full guide on the postural ratings can be found in Appendix 3. This method was used because it fit the nature of the trial, where not a lot of time was available to get through a number of fitness tests. A better option in the context of horse riding in a field environment would have been detailed postural assessments by a physiotherapist, but because time was limited at the testing sessions the convenience of only having to take pictures and being able to assess at a later stage outweighed the accuracy of in depth postural analysis. It was accepted that minor postural changes would not be possible to detect with this method, but more obvious changes in posture would be apparent. Posture was only measured in the intervention trial.

Figure 3.5: Posture photos from an anterior, posterior, right and left view with the added grid for postural analysis. (*Source:* The author, 2015)

Intervention programme

Subjects that took part in the intervention programme (n=23) followed the above outlined protocols at the first testing. They were then instructed in a small group setting by a qualified Pilates instructor on how to perform the exercises they were asked to do at home. This session lasted approximately half an hour and was scheduled to ensure that all subjects would know how to correctly execute the exercises. The subjects were then handed an information pack (Appendix 4) outlining how to do the five different exercises in case they needed it for reference at home. An exercise diary was also handed out in which the subjects were asked to record each time they performed the exercise programme. The minimum requirement to stay in the study was three times per week. Half way through the ten-week trial the subjects were again instructed by the Pilates instructor on how to correctly perform the exercises. Retesting was carried out at the end of the ten weeks with the same protocol as pre-intervention. The subjects acted as their own controls, because the number of volunteers that were available was too little to allow for separation into a test and a control group. The author is aware that this might compromise the validity of the trial slightly.

3.5 Pressure distribution

Pressure distribution was measured with a TekScan pressure mat (Tekscan Inc., South Boston, MA, USA). The pad was placed inside of a specially made saddlecloth that was fitted under the saddle of the mechanical horse. Markers that were attached to the mechanical horse and the pressure mat ensured that the pressure mat was accurately aligned for every testing. The data was collected via a WIFI device that was attached to the pressure mat and sent the signal straight to the laptop, which recorded the pressure data. The pressure readings were taken in all three gaits for approximately 25 seconds at the same time as their video recordings were taken. No syncing of data was possible during this study due to the lack of more advanced equipment. The subjects were asked to identify their weight by standing on the same scales and the result in kg was used for calibrating. The measurement that was chosen was the peak pressure reading that was recorded in kilopascal (KPa) of four areas of the pad. Both left and right anterior peak pressure readings were added up to gain the anterior peak pressure. This same system was used for posterior as well as left and right pressure readings (Figure 3.6). The TekScan system only became available at a later stage which is why only about half (n=17) of the subjects in the cross-sectional study were recorded.

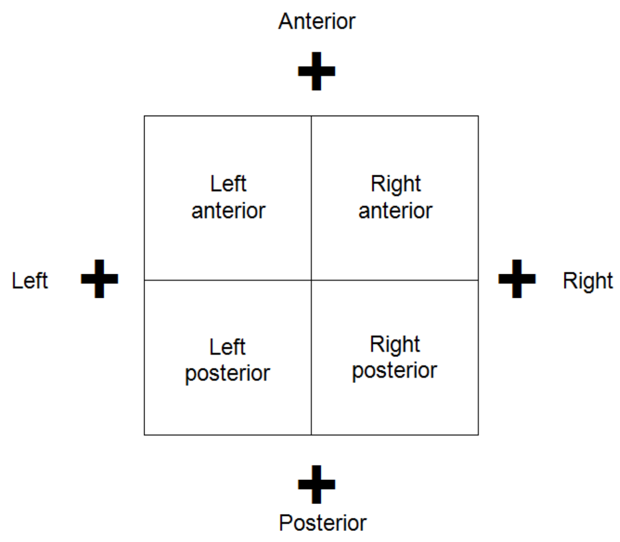

Figure 3.6: Pressure distribution calculations explained. The pressure recordings that were available from the TekScan saddle pad are the ones within the squares. Because these were only of limited use for this study the ones on the outside were calculated by adding the two peak pressure readings together that were closest to the plus sign.

3.6 Statistical analysis

All data was imported to the IBM SPSS Statistics version 21 (IBM Corporation, Armonk, NY) for statistical analysis. A Kolmogorov Smirnov test was used to assure that all data was normally distributed and thus parametric. Descriptive statistics were used to understand the distribution of the different data sets.

Pearson's chi-squared test was used to establish whether there was a significant difference between expected and observed frequencies for the questionnaire. Riding position angles were analysed using the Pearson's two-tailed bivariate correlations to test for the relationship between angles as well as between angles and fitness parameters and within fitness parameters. The same was done with pressure distribution. Independent samples t-tests were used to investigate differences within data sets. For the intervention trial pre and post intervention data was compared using the paired samples t-test. For all statistical tests the confidence level of 95% probability was used to establish significance ($P<0.05$).

3.7 Conclusion

As previously mentioned some of the ways that data was collected could be classified as less ideal for a horse-riding context. Subject recruitment was also to be taken into consideration because of which the majority of tests could not go into a lot of detail due to time restrictions. Altogether the methodology that has been developed is believed to be of a good quality standard and results are going to be valuable to the industry even if particular areas could have gone into more detail.

Chapter 4

Questionnaire investigating the perceived importance of off-horse exercise on riding position

Parts of this research study were presented at the 2014 BASES Annual Student Conference, Portsmouth (Prentice, J. (2014) 'Perceived importance of off-horse exercise on riding position', Book of Abstracts, 209.)

4.1 Introduction

Anecdotal evidence suggests that fitness parameters are beneficial to riding position, because the rider is able to work towards an ideal balance of posture without the kinetic forces of the horse acting upon him. This counteracts the cycle of imbalances that horse and rider force upon each other. The belief is that improved off-horse alignment will aid mounted position. Few studies have been carried out on the physiological demands of riding. The energy expenditure was investigated by Westerling (1983) and Devienne and Guezennec (2000) whereas Terada *et al.* (2004) and Probin (2014) investigates muscle usage. Riding position has been studied by Schils *et al.* (1993) and Lovett *et al.* (2004) and more specifically rider asymmetry has been researched by Symes and Ellis (2009) and Muenz *et al.* (2014). Even fewer studies have looked at intervention programmes with which riding position could be improved; however, through a number of studies assumptions have been made that riding position can be improved through off-horse measures. Nevison and Timmis (2013) investigated physiotherapy as a solution to eliminate medio-lateral asymmetry with success and others have reported core stability based exercise programmes to positively impact riding position. (Wilkinson and Graham, 2006; Sudhoff, 2010). Despite the recent increase in interest from a research point of view, as well as information available on the subject, exercise classes for horse riders are not commonly available for participation. It is unclear whether the average horse rider is aware of the possible effects of his fitness on the wellbeing and performance of his horse. This study has been designed to investigate the perceived importance of off-horse exercise on riding position by the wider equestrian population.

4.2 Aims and Objectives

Research Aim

The proposed research seeks to investigate the exercise habits of equestrians as well as their perceived importance of off-horse exercise in improving riding position. In order to make recommendations, the factors that make riders more or less likely to believe in and participate in off-horse exercise will also be explored.

Research Objectives

Objective 1: To gather information about the general demographics of equestrians to establish whether a representative sample of this population was reached, to enquire about their riding habits to find out what type of rider they can be classified as and to determine their view on the importance of off-horse exercise.

Objective 2: To investigate relationships within the dataset between general demographics, riding habits and perceived importance of off-horse exercise - i.e., looking at who it is that would be more likely to participate in off-horse exercise, etc.

Objective 3: To understand the views on certain fitness parameters and their impact on riding position.

Objective 4: To advise under what circumstances horse riders are willing to attend local exercise classes specifically tailored to the equestrian.

4.3 Methodology

Survey design

A questionnaire was developed to run on the cloud based service "Google Drive" (https://drive.google.com). The introductory text was formulated with all necessary information and all respondents that completed the questionnaire were assumed to have given informed consent. Before publication a pilot was run to eliminate errors in data collection (see Chapter 3.2) and approval of the Writtle College Ethics Committee was granted. The questionnaire was written in three sections, with the first section focussing on the general demographic of the respondents. Participants were asked about their age, gender and annual income as well as the geographical area in which they live. The survey was particularly designed for respondents within the UK, but could also be completed by those residing outside the UK. This section was partly adapted from the British Equestrian Trade Association's 2011 National Equestrian Survey, so that the results could be compared to identify the validity of the sample group. The question regarding annual salary was changed from socio-economic groups to salary brackets to gain a better understanding of the individuals' income. The information on income was important to know to be able to establish if extra income would make respondents more likely to participate and therefore pay for off-horse exercise. The National Equestrian Survey was also only aimed at British horse riders, which is why the option of "outside the UK" was added to the regions. The second section focussed on obtaining information about their riding habits. Information such as the number of years of riding experience, main discipline, riding tuition, confidence on the horse, competing habits, amount of horses kept, the nature of how these horses are kept, etc. This section was designed with the help of two equestrian coaches to gain the best insight into the individuals' horse riding experience and habits. The idea of this section was to understand how the individuals had access to horses and at what level they were involved in keeping those horses. This was interesting because looking after horses is a very practical responsibility that would involve often very one-sided physical activity (i.e. mucking out, sweeping, as this is usually carried out with the same hand leading). It was also of interest to know at what level the subjects rode, to establish how important good riding position would be for their success, and where their horse riding education came from. Finally, the last section referred to the off-horse exercise habits of respondents. This was composed of questions about the nature and frequency of the respondents' off-horse exercise habits as well as the perceived importance of off-horse exercise on riding position and the views on the impact of particular fitness components on riding position. The respondents were also asked to identify if and under what circumstances they would be interested to take part in an exercise class specifically tailored to equestrians. The questionnaire was designed in a way that some questions were compulsory and the respondents could not move on without having answered that particular question. A pilot study was carried out on 20 individuals who were asked to identify problems in understanding the questions, missing answers to closed questions and other issues they found with the questionnaire. Some answers were added before the questionnaire was made available to the public. Which questions were amended and how is shown in Table 4.1. The complete questionnaire can be referred to in Appendix 2.

Table 4.1: Changes made after Pilot study.

Question 7	The answer "I ride for other people" was added.
Question 8	The answer "Lives out" was added.
Question 10	The answers "Showing" and "Hunting" were added.

Survey distribution

The questionnaire was mainly publicised through the social networking site “Facebook”. The link to the “Google Drive” site hosting the questionnaire was posted to various Horse riding related groups and pages. Contacts within UK equine journalism, governing bodies, societies and the equine industry were approached via email or social networking sites and were asked to share the link to the online questionnaire via email or on their social networking pages/groups.

Survey analysis

The questionnaire was online and available for response for four months. Data was automatically collected in Excel format (Microsoft Corporation, Redmond, WA) on the Google drive and downloaded at the closing of the questionnaire. The data was then transferred to IBM SPSS Statistics version 21 (IBM Corporation, Armonk, NY) for analysis. Some of the data was collected in exact measures so this had to be put in categories for the analysis, i.e. the questionnaire asked for the exact age and amount of years the respondents had been riding. Descriptives were generated in SPSS and the tables and figures were produced with Excel. A Pearson Chi-Squared test (χ^2) was used to check for associations between the respondents’ demographics, riding habits and perceived importance of off-horse exercise. The 5% significance level ($P<0.05$) was used. The frequency of some groups was insufficient to examine every relationship because of which some data needed to be grouped where appropriate.

4.4 Results

Frequencies in responses to the questionnaire

Between 09/04/2013 and 10/08/2013 526 responses were collected. Two of these were discarded as the respondents were not regular riders and thus did not match the criteria for the questionnaire leaving 524 valid sets of data (n=524). The general demographic data as adapted from the BETA survey has been summarised in the demographics table 4.2 below.

Table 4.2: Demographics of the respondents.

Demographic	Group	Count	Percent	BETA	n
Gender	Male	22	4.2%	27%	524
	Female	502	95.8%	73%	
Age	Average ± St. Dev.	31.62 ± 12.46			523
	Range	23 – 68			
	Under 25	198	37.98%	48%	
	25-34	141	26.91%	32%	
	35-44	87	16.60%	*	
	45 and over	97	18.32%	20%	
Income	< £15.000	211	40.3%		524
	£15.000-£24.999	78	14.9%		
	£25.000-£34.999	58	11.1%	**	
	£35.000-£44.999	33	6.3%		
	> £45.000	58	11.1%		
	Prefer not to say	86	16.4%		
Geography	South East	183	34.9%	23%	523
	Wales/South West	61	11.6%	17%	
	Midlands	46	8.8%	16%	
	North West	26	5.0%	8%	
	Greater London	23	4.4%	13%	
	North East	22	4.2%	17%	
	Scotland	12	2.3%	6%	
	Northern Ireland	3	0.6%		
	Outside UK	148	28.2%		
	Australia	57	10.9%		
	Europe	45	8.6%		
	Northern America	42	8.0%		
	Africa	2	0.4%		
	Asia	2	0.4%		

*Please note that the BETA survey used the category 25-44 years.
**Income could not be compared as the BETA survey did not specify an annual income but a socio economic group of the chief earner in the household.

Years of riding experience of respondents

Due to respondents answering with "0" and "278" two of the responses were not usable and have been classed as missing. The data was collected in exact years with the mean and standard deviation of 21.73 ± 11.85 years and was grouped into categories for the purpose of presentation. The majority of respondents have been riding for eleven to 25 years (284, 54.2%) followed by those that have been riding for more than 15 years (159, 30.3%). Only a few responses have taken up riding within the last five years (23, 4.4%) and the remaining have been riding for the past five to ten years (56, 10.7%).

Respondents' average time spent riding each week

The largest group reported to be riding six or more hours per week (184, 35.1%) whereas those riding one hour per week (34, 6.5%) was found to be the smallest group. Those that ride less than one hour per week (51, 9.7%) were the second smallest group and in between these extremes the remaining respondents stated that they ride two to three hours (115, 21.9%) or four to five hours (140, 26.7%) in an average week. The respondents' distribution of the time spent riding in an average week is shown in Figure 4.1.

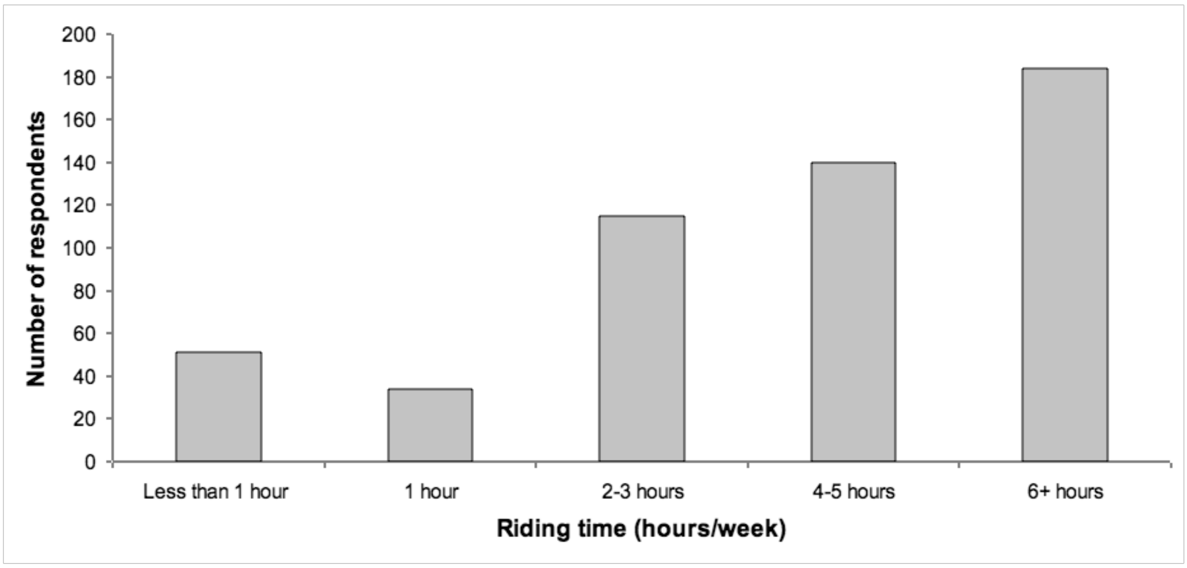

Figure 4.1: Hours spent riding per week (n=524)

Respondents access to a horse

The majority of respondents stated that they either own or loan a horse (397, 75.8%). Other ways of accessing a horse were sharing (24, 4.6%), riding for other people (41, 7.8%), riding in a riding school (28, 5.8%) or riding as part of a job (34, 6.5%).

Type of livery used by respondents

Asking for the type of livery used was important to establish how much physical exercise is already catered for by yard work. Depending on the type of livery the respondents use a certain amount of activity can be assumed. Respondents that stated that they keep their horses at home or own stables were grouped into the DIY category unless they stated that their horses were living out in own fields or similar. One respondent simply stated how many horses they look after and one stated ‘working pony’. Because these answers were inconclusive they were classed as missing data. Horses were found to be looked after mainly on a DIY basis (257, 49%). Other ways of looking after horses were Full/Part livery (102, 19.5%) and Grass livery (105, 20%). A number of respondents do not look after a horse altogether (54, 10.3%)

and other responses included keeping a horse at work or 'all the above' (4, 0.8%). The distribution of how the respondents' horses are kept is shown in Figure 4.2.

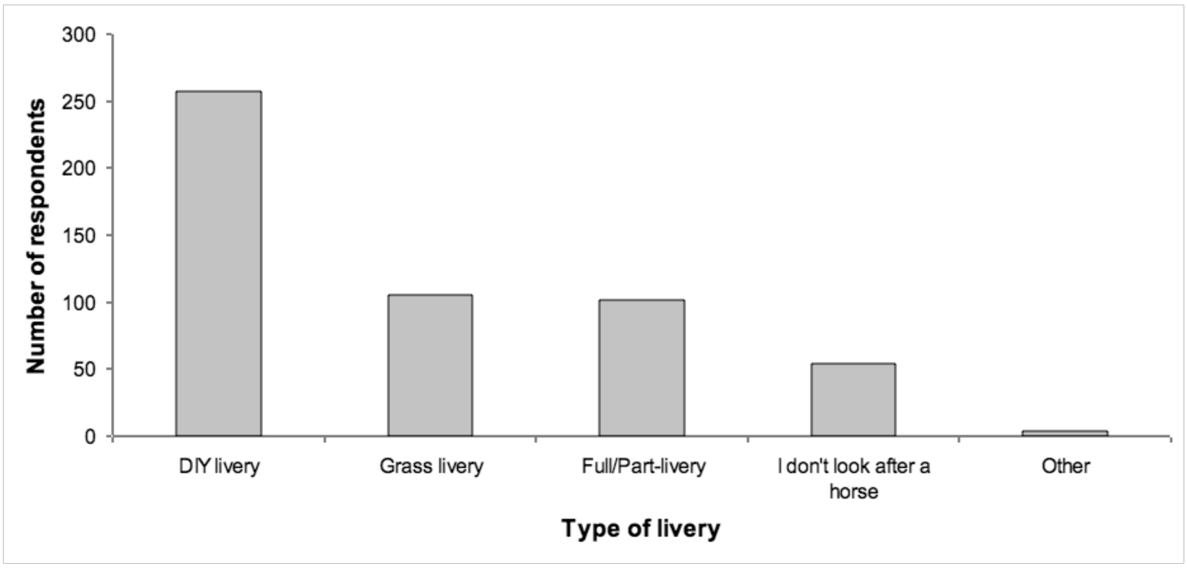

Figure 4.2: Type of livery in which the respondent's horse is kept (n=524)

Number of horses ridden by the respondent during a normal week

To understand the situation of the respondents it was asked how many horses he normally rides per week. This would indicate amateur or professional status and whether the respondent was more of a leisure rider. Most respondents ride only one horse per week (237, 45.2%). Almost as many ride two to three horses (212, 45.2%) and the remainder ride four horses or more in a normal week (75, 14.3%).

Respondents' main discipline

Those disciplines that were only represented a handful of times have been grouped as "other" for presentation and analysis purposes. These come to a total of 71 responses (13.5%). The two biggest categories being leisure and dressage riders at 160 (30.5%) and 142 (27.1%) respondents respectively declaring these their main disciplines. Eventing follows with 74 (14.1%) of respondents. 41 (7.8%) and 36 (6.9%) respondents associate with show jumping and riding club activities as their main disciplines. Other disciplines include western, endurance, showing, hunting, natural horsemanship, polo, combined training, roping cattle work, vaulting, campdrafting, classical riding, mustering, trail riding, driving, gaited horses, jump cross, mounted combat, agility and point to point racing. The distribution of respondent for the main disciplines and other is shown in figure 4.3.

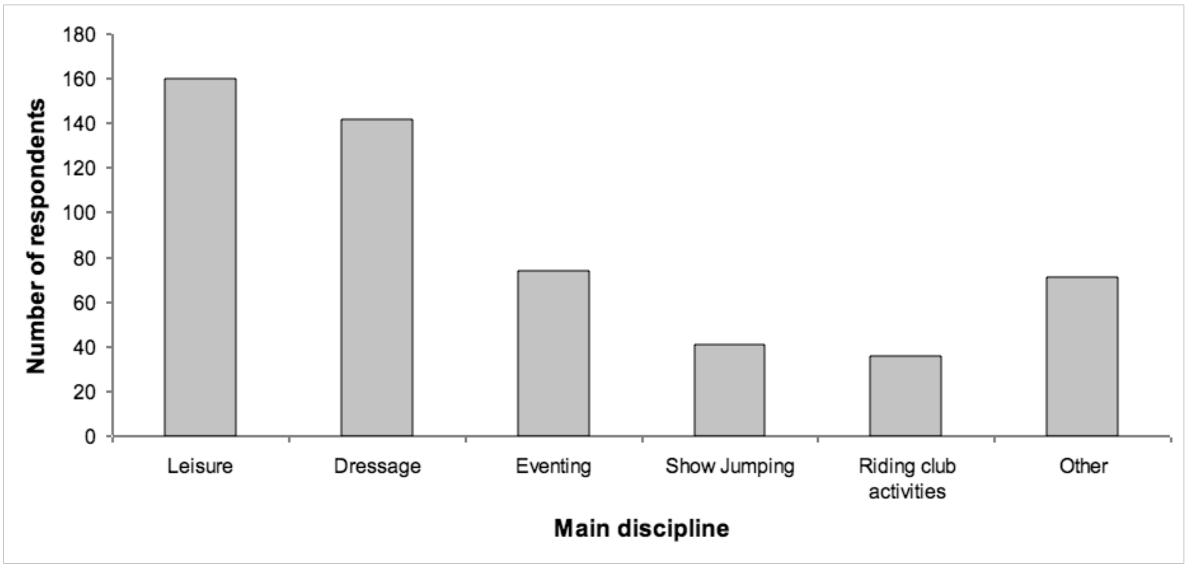

Figure 4.3: Respondents main discipline (n=524)

Respondents' participation in riding tuition

Riding tuition habits have been summarised in table 4.3 below. The respondents that answered the question on discipline during tuition with "other" received tuition primarily in eventing, but also carriage driving, natural horsemanship, agility, jump cross, western, trail riding, circus, biomechanics, showing, clicker training, classical riding, gaited horses, connected riding and side saddle.

Table 4.3: Respondents participation habits for riding tuition.

	Answer	Count	Percent	n
Tuition	Yes	362	69.1%	524
	No	162	30.9%	
Discipline	Dressage	233	63.3%	368
	Show jumping	76	20.6%	
	Both	26	7.1%	
	Other	33	9%	
Frequency	Several times per week	35	9.3%	376
	Weekly	109	29.0%	
	Fortnightly	81	21.5%	
	Monthly	151	40.2%	

Secondary activities undertaken to improve riding

This question was designed in a way that the respondents could select one or more options as appropriate for them. Roughly one fifth of respondents (92, 17.5%) stated that they don't participate in any off-horse activity to improve their riding with the remaining (432, 82.5%) engaging in one or more activity aside from riding. The distribution of respondents' activities to improve riding other than having riding tuition is shown in Figure 4.4. Apart from receiving riding tuition 346 (66.0%) respondents stated that they read articles online and in magazines to improve their riding. Another 265 (50.6%) respondents visit Masterclasses, Lecture Demo's or watch instructional videos. Though off-horse exercise was not an option that was provided, as this was inquired about later on in the questionnaire, 53 respondents (11.3%) indicated in the other category that they participate in off-horse exercise to improve their riding. There were enough respondents so that this could be grouped as a separate category. 32 respondents stated that they participate in other activities to improve their riding. These were watching others, videotaping their riding and asking for critique, training camps and following research on equestrianism.

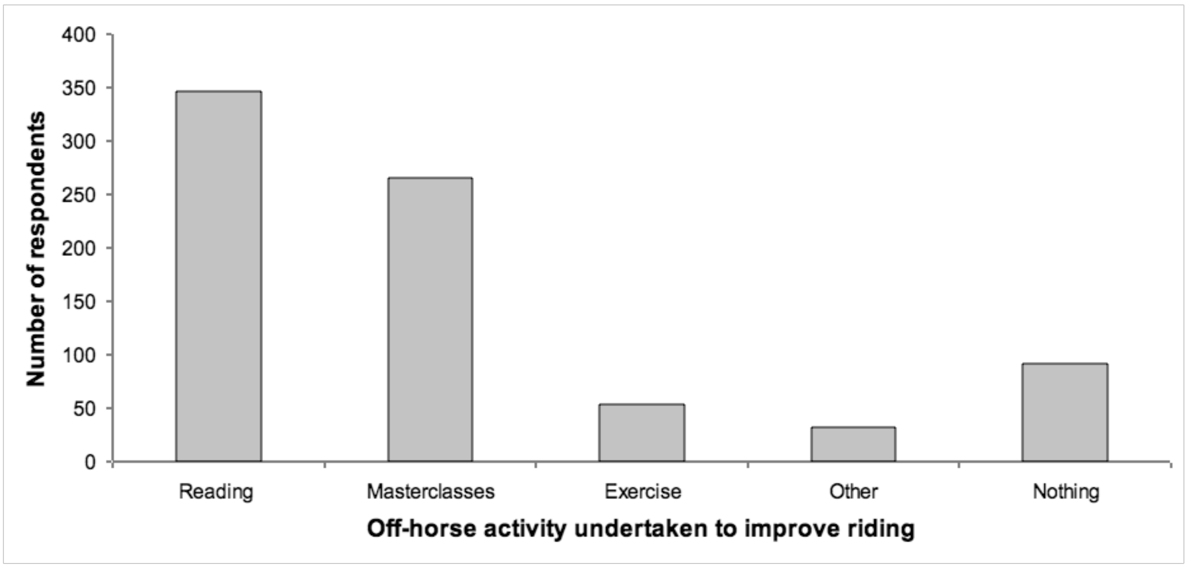

Figure 4.4: Secondary activities undertaken by respondents to improve riding

Level of competition

An extensive list of experiences was drawn up in collaboration with two experienced riding instructors based on common levels of competition but supplemented by levels below competition standards. The participants were asked to class themselves in the highest level of competition that they had taken part in. The results are listed in table 4.4 and show that most respondents were of a more novice and relatively basic level of competition. For the purpose of analysis, the respondents were grouped into three categories dependent on the type of competition they partake in. Out of the group

(179, 34%) that compete affiliated, 15.8% (83) compete in advanced classes (starting from BD Medium, BSJA Foxhunter or BE Novice depending on discipline). The largest group of respondents are competing unaffiliated (229, 43.7) and the remaining have taken part in any competition due to the nature of their riding being purely recreational (116, 22.1%). The distribution of affiliation status is shown in Figure 4.5.

Table 4.4: Highest level of competition the respondent has taken part in (n=524)

Level of competition	Frequency	Percent
Beginner	11	2.1
Recreational Hacking (walk and trot)	10	1.9
Recreational Hacking (including canter and gallop, maybe some smaller obstacles)	58	11.1
Recreational Hacking (including jumps above 80cm)	37	7.1
Unaffiliated Dressage Preliminary/Unaffiliated Show Jumping up to 80cm/Unaffiliated Eventing up to BE80 equivalent	87	16.6
Unaffiliated Dressage Novice/Unaffiliated Show Jumping 80cm to 1m/Unaffiliated Eventing intro BE90 equivalent	95	18.1
Unaffiliated Dressage Elementary/Unaffiliated Show Jumping/Unaffiliated Eventing Pre-Novice Be100 equivalent or above	47	9.0
BD Preliminary/BSJA British Novice/BE80	14	2.7
BD Novice/BSJADiscovery/BE90	40	7.6
BD Elementary/BSJA Newcomers/BE100	42	8.0
BD Medium/BSJA Foxhunter/BE Novice	34	6.5
BD Advanced-Medium/Show Jumping1.30m/BE Intermediate	26	5.0
Prix St.George Dressage/Show Jumping 1.40m/BE Advanced	14	2.7
Grand-Prix Dressage/Show Jumping 1.50m/Point to Pointing	9	1.7

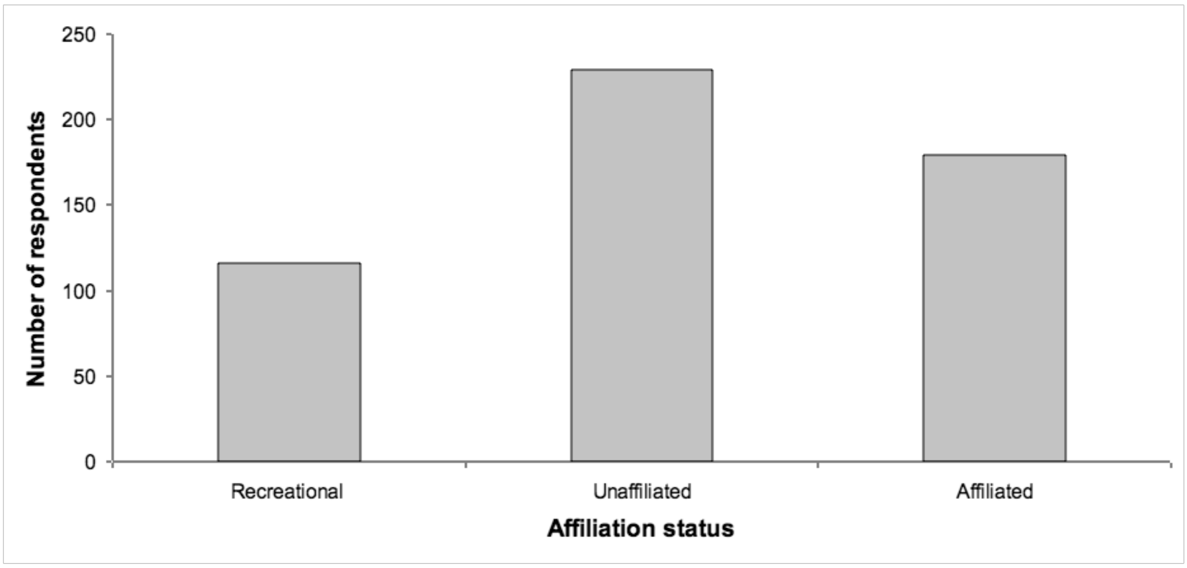

Figure 4.5: Level of competition grouped by affiliation status

Level of schooling

The same question was asked again to distinguish between the highest level of schooling the respondents had ever done as opposed to the highest level they had competed at as it is recognised that more advanced movements and techniques may be tried out at home, but not necessarily competed in. Roughly one quarter of respondents (137, 26.1%) class their affiliation status as recreational and do not compete. Out of the competing respondents 195 (37.2%) have schooled to a level of unaffiliated events and 192 (36.6%) have schooled to the equivalent of affiliated events. Out of the affiliated lot 118 (22.5%) have schooled to a level of BD Medium, BSJA Foxhunter or BE Novice or above. The distribution of the highest level of schooling the respondents have taken part in is shown in Table 4.5 with the distribution of affiliation status being shown in Figure 4.6.

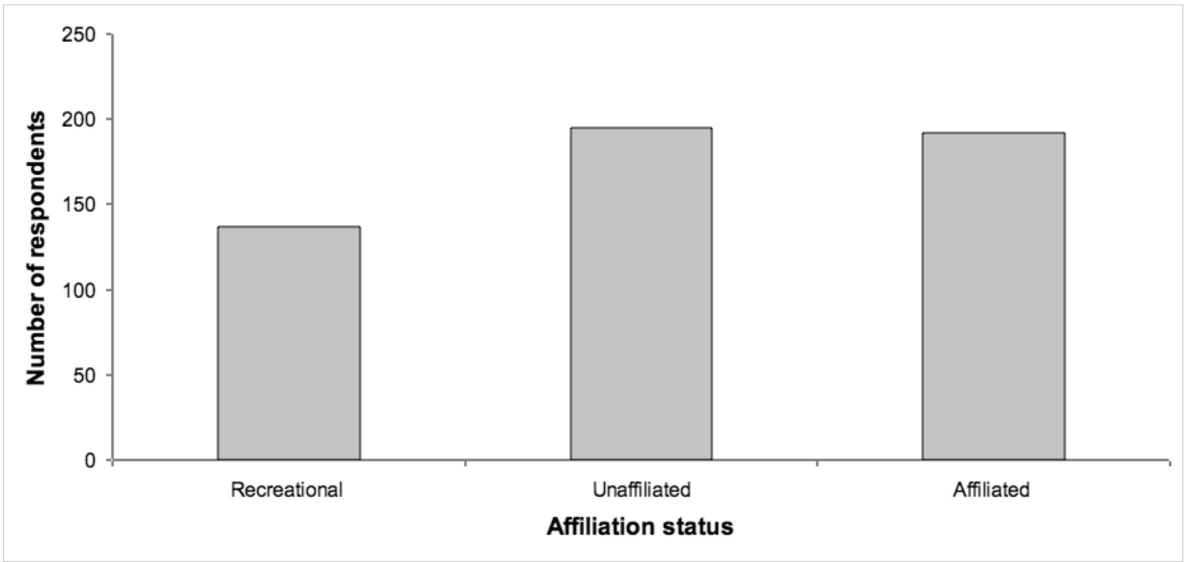

Figure 4.6: Level of schooling grouped by affiliation status (n=524)

Table 4.5: Highest level of schooling the respondent has done at home (n=524)

Level of competition	Frequency	Percent
Beginner	6	1.1
Recreational Hacking (walk and trot)	15	2.9
Recreational Hacking (including canter and gallop, maybe some smaller obstacles)	70	13.4
Recreational Hacking (including jumps above 80cm)	46	8.8
Unaffiliated Dressage Preliminary/Unaffiliated Show Jumping up to 80cm/Unaffiliated Eventing up to BE80 equivalent	57	10.9
Unaffiliated Dressage Novice/Unaffiliated Show Jumping 80cm to 1m/Unaffiliated Eventing intro BE90 equivalent	72	13.7
Unaffiliated Dressage Elementary/Unaffiliated Show Jumping/Unaffiliated Eventing Pre-Novice Be100 equivalent or above	66	12.6
BD Preliminary/BSJA British Novice/BE80	6	1.1
BD Novice/BSJADiscovery/BE90	19	3.6
BD Elementary/BSJA Newcomers/BE100	49	9.4
BD Medium/BSJA Foxhunter/BE Novice	48	9.2
BD Advanced-Medium/Show Jumping1.30m/BE Intermediate	39	7.4
Prix St.George Dressage/Show Jumping 1.40m/BE Advanced	19	3.6
Grand-Prix Dressage/Show Jumping 1.50m/Point to Pointing	12	2.3

Confidence level of respondents

To gain an understanding of the respondents' willingness of risk taking whilst riding this question was designed on confidence level. The distribution is shown in Figure 4.7. Only very few people classed themselves as a new rider (3, 0.6%) so that this category was grouped together with those that consider themselves novices (35, 6.7%) for statistical analysis. The group of respondents who considered themselves advanced in their level of risk taking was the largest (221, 42.2%) followed by the experienced or professional (146, 27.9%) and the intermediate_(119, 22.7%). For a detailed explanation of the different levels please refer to table 4.6.

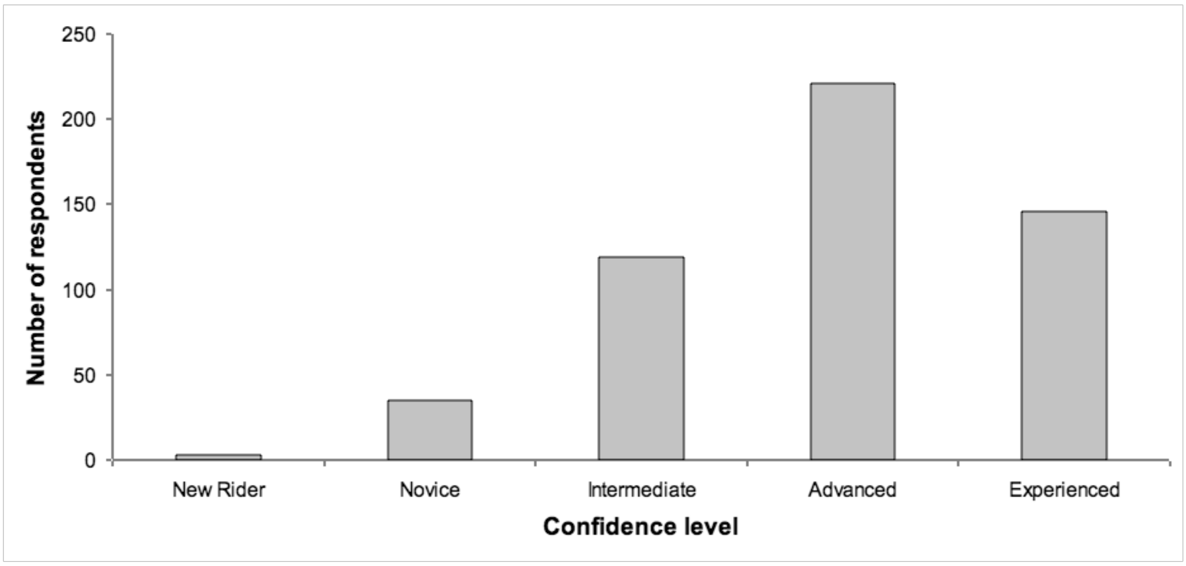

Figure 4.7: Willingness of risk taking of the respondents (n=524)

Table 4.6: Explanation of confidence level categories as used in the questionnaire.

Category	**Explanation**
New rider	You can walk and trot in an enclosed arena or you may have no riding experience.
Novice	You can mount and dismount, walk and rise to a trot and canter in an indoor school or outdoor arena. You may have done some hacking out and are starting to jump.
Intermediate	You ride regularly may have competed at local level or done some long-distance riding. You will be used to riding out in the company of others and be able to control your horse at walk, trot and canter and are able to jump up to 90 cm confidently.
Advanced	You do not feel nervous on a variety of horses in an enclosed arena. You are used to hacking out alone and in the company of others. You can control your horse outside in all gaits including gallop and are comfortable with cross-country jumping. You will have previous experience of several different horses.
Experienced	You will have competed, hunted or taken part in team chasing. You have experience and are confident over difficult terrain and can control a horse at all paces including galloping and jumping over a variety of obstacles. You have previous experience of many horses. You may have spent many years, either working with horses, riding daily or competing at a National or International level.

Participation in off-horse exercise

Almost a quarter of people stated that they do not participate in any other form of exercise apart from horse riding (111, 21.2%). Most respondents stated that they engage in secondary exercise, which mainly comprised of walking. The distribution of whether respondents partook in secondary exercise is shown in Figure 4.8 and a detailed list of secondary exercise habits is displayed in Table 4.7. To move on with the questionnaire respondents were required to indicate the frequency for each of the different sporting disciplines. To investigate the respondents' reasons for additional exercise the respondents could tick as many as they felt were true for them. A total of

1600 responses were submitted. The distribution of responses regarding the reason for secondary exercise is shown in Table 4.8. The main reasons for secondary exercise are reported to be improving aerobic fitness and keeping fit closely followed by the motivation of weight loss. The fourth most common reason of secondary exercise in this sample of respondents is to improve their riding. Practical reasons such as having to exercise as a method of transport or dog walking are less common and further down the list. Other reasons include being employed in the fitness industry or training to be recruited for a physically demanding job.

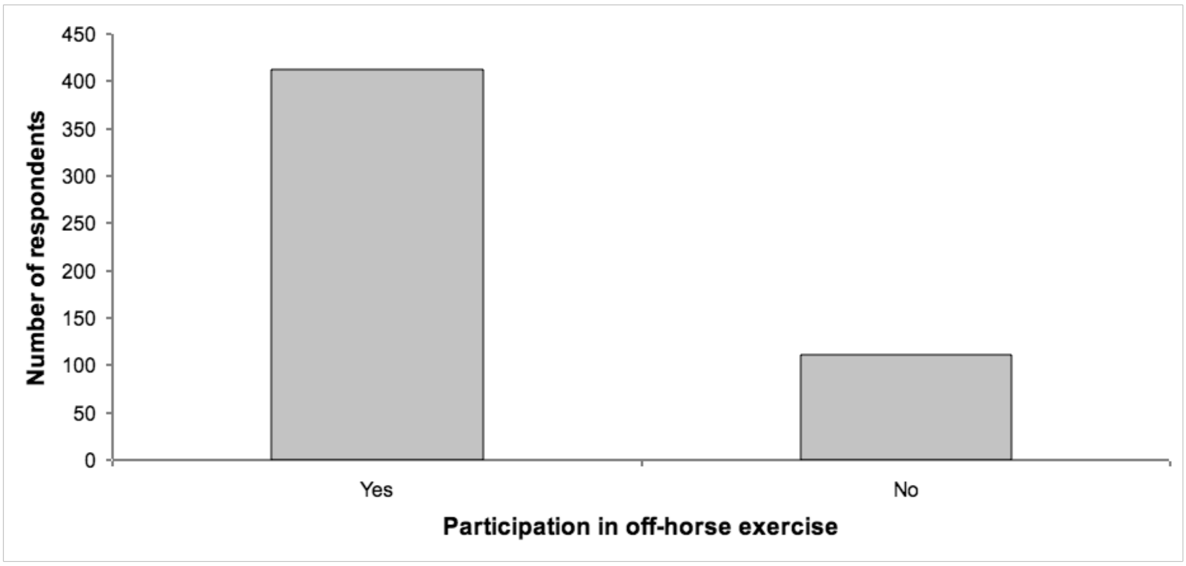

Figure 4.8: Participation in exercise other than riding (n=524)

Table 4.7: Specification and frequency of off-horse exercise (n=524)

	Frequency				
Sport	**Daily**	**Several times a week**	**Fortnightly**	**Occasionally**	**Never**
Walking	245	124	18	85	52
Cycling	16	62	36	186	224
Running	15	97	45	131	236
Pilates/Yoga	11	71	45	111	286
Swimming	4	35	55	203	227
Teamsport	1	34	27	73	389
Dance fitness	6	27	39	92	360
Gym	9	27	4	9	475
Other	18	36	17	38	415

Table 4.8: Respondents reasons for off-horse exercise (n=524)

Reason	**Number of respondents**
Aerobic fitness	317
Keep fit	304
Lose weight	197
Improve riding	181
Alternate hobby to riding	175
Musculo-skeletal suppleness	163
Improve posture	118
Method of transport	107
Dog walking	22
Other	16

Average monthly spending on fitness

Out of the total six answers had to be classified as missing due to inconclusive data. The respondents had stated “not much”, “?”, “20 hours”, “30 hours”, “not enough” and “8 hours per week”. The money spent on fitness per month ranged from £0 to £500 with an average of £27.27 ± £47.63. The distribution of the respondents’ average spending on fitness per month was grouped for statistical analysis. A large group of people stated that they do not spend any money on fitness (214, 41.3%). The amounts of respondents decreased from spending less than £25 (112, 21.6%) £25-£49 (88, 17.0%) and £50-£99 (63, 12.2%) to more than £100 (41, 7.9%) per month.

Off-horse exercise and riding position

The clear majority of respondents (88.9%) answered that they do believe that off-horse exercise has an impact on their riding. The remaining respondents (11.1%) do not share this view and do not believe that off-horse exercise has an impact on their riding. A little less than half of the respondents (244, 46.6%) state that they participate in off-horse exercise to improve their riding. The remaining other 280 (53.4%) do not participate in off-horse exercise particularly to improve their riding. Out of the total 524 responses 26 of the respondents (5.0%) chose the other option without specifying what the aspect they hope to improve was, making these answers incomplete. They were classified as missing. A very small number of respondents (5, 1.0%) stated that they do not hope to improve any aspect of their riding. Riding position was hoped to be improved by off-horse exercise, by more than half of the respondents (269, 51.3%). Some were concerned with their endurance and hoped to delay fatigue (109, 20.8%) or improve their cardiovascular endurance (99, 18.9%). The remaining respondents (16, 2.3%) wished to improve other aspects of their riding which include improving balance, coordination, mental awareness, all the above, core strength, flexibility, weight maintenance and suppleness. A summary of the off-horse exercise habits in particular context to riding performance can be seen in Table 4.9 below.

Table 4.9: Respondents view and participation on off-horse exercise.

	Answer	Count	Percent	n
Impact on riding position	Yes	466	88.9%	524
	No	58	11.1%	
Participation	Yes	244	46.6%	524
	No	280	53.4%	
Aspect to be improved	Riding position	269	51.3%	498
	To delay fatigue	109	20.8%	
	Being out of breath	99	18.9%	
	Other	16	2.3%	
	None	5	1%	

Fitness component perceived to have the biggest impact on riding position

The distribution of which fitness component the respondents perceive to have the biggest impact on riding position is shown in Figure 4.9. The majority of respondents (308, 58.8%) believe that core-stability has the biggest impact on riding position. Balance is believed to have the biggest impact by 83 respondents (15.8%) closely followed by posture with 67 respondents (12.8%). Cardiovascular endurance and Flexibility are believed to have the biggest impact by the least amount of people with 46 (8.8%) and 20 (2.8%) votes respectively.

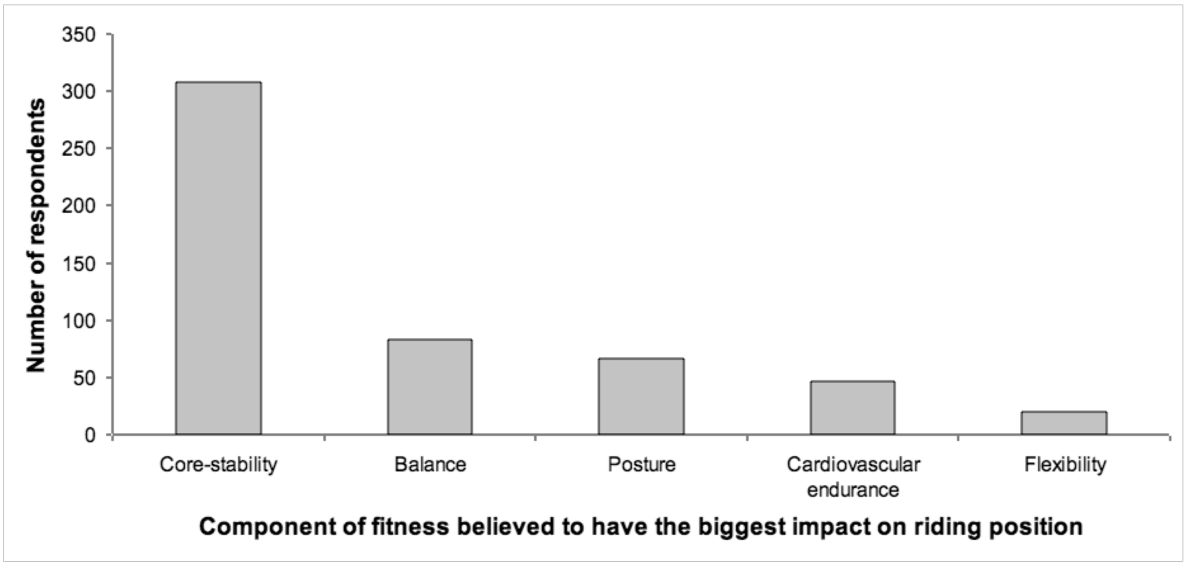

Figure 4.9: Respondents view on which fitness component has the biggest impact on riding position (n=524)

Willingness to attend equestrian exercise class

To find out if there was a demand for exercise classes particularly tailored to equestrians, the willingness and limitations to taking part in such class were investigated. It should be noted that the respondents could tick more than one answer. The distribution of the respondents' views on this is shown in Figure 4.10. A small group of respondents (83, 15.8%) would not attend an off-horse exercise class tailored to equestrians, whereas some respondents (9, 1.7%) would attend, regardless of the distance or cost. For the majority (194, 56.2%) cost is the main limiting factor with 169 (32.3%) wanting to attend if the class would cost less than £5.00 and 125 (23.9%) being willing to spend up to £10.00. Another large group (119, 22.7%) state that they would be interested to take part if the class was no further than 10 miles away. The remaining 23 respondents (4.4%) are concerned with other limitations stating for that they would be willing to attend if the class was even closer, if the right kind of exercises would be included or if the time of the class would fit into their schedule.

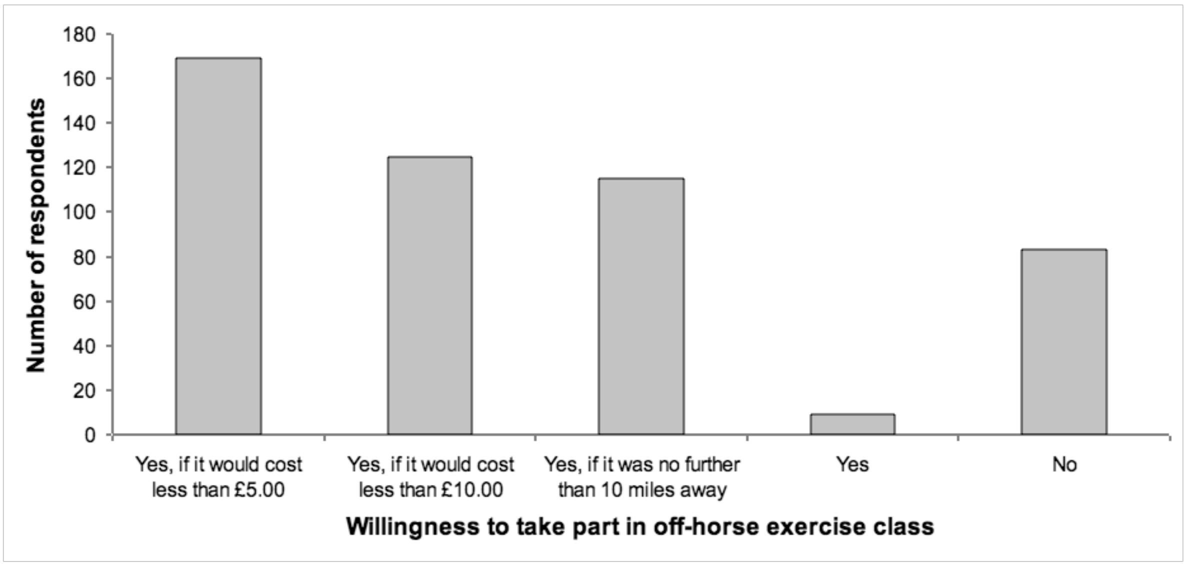

Figure 4.10: Respondents willingness to take part in an off-horse exercise class (n=722)

Level of agreement with the statement that off-horse exercise is an important part of improving riding ability

The respondents were asked to choose their level of agreement with the following statement: "*Off-horse exercise is an important part of improving riding ability, because it gives the rider a chance to work on their weakness without the impact of the horse's problems."* The largest group of people agreed (348, 66.4%) with the above statement followed by those that neither agreed nor disagreed (95, 18.1%). Only 81 respondents disagreed (15.5%). The distribution of the respondents' agreement is shown in Figure 4.11.

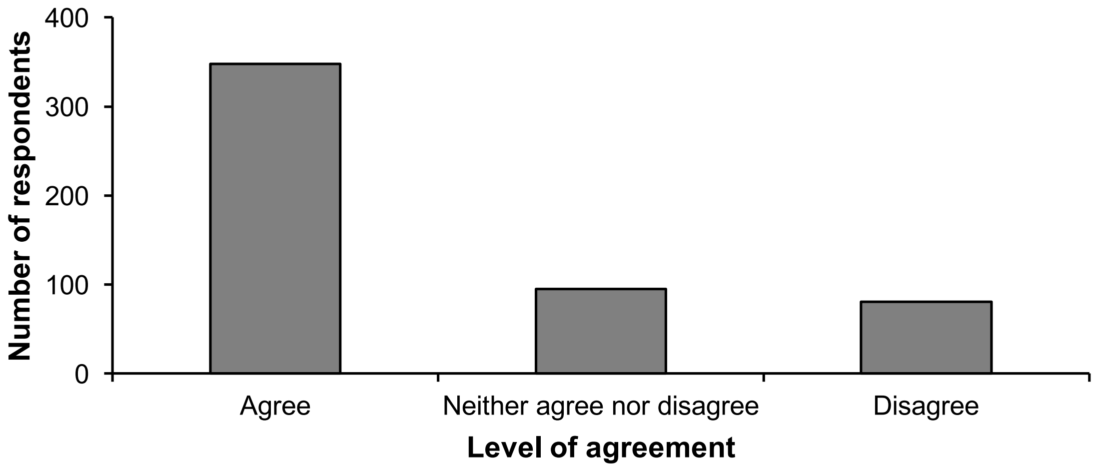

Figure 4.11: Respondents level of agreement with exercise being an important part of improving riding ability (n=524)

Associations between responses to the questionnaire

The only differences between male and female respondents were found in whether or not they received riding tuition (Figure 4.12) with women being more likely to have riding lessons than men ($\chi 2=8.535$; df=1; $P<0.01$) and also more frequently ($\chi 2=6.257$; df=2; $P<0.05$).

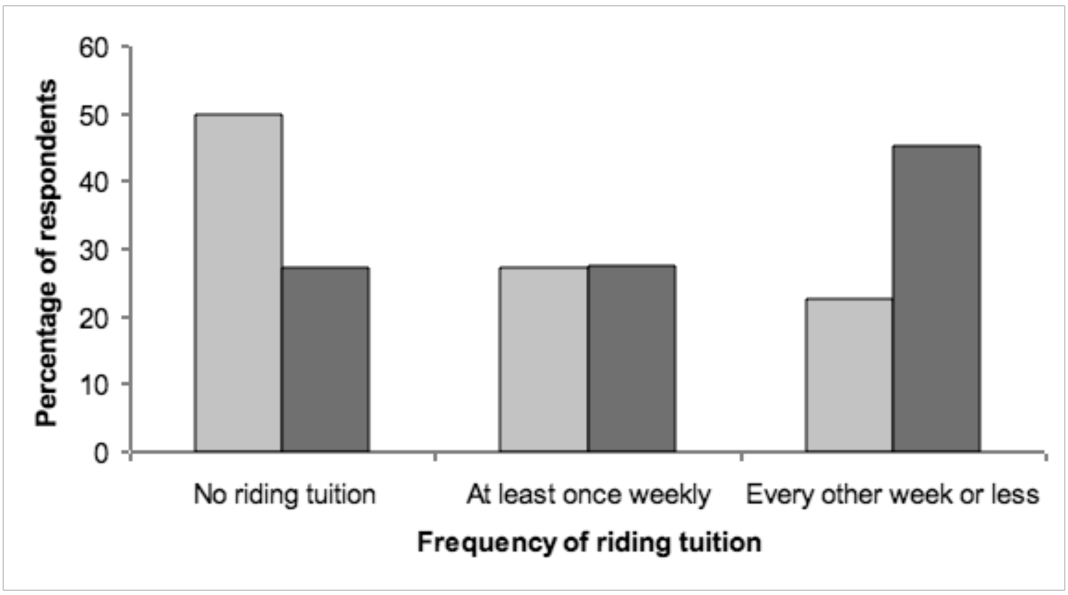

Figure 4.12: Significant association between gender and the frequency in which they receive riding position. The light grey bars representing the men and the dark grey representing the women.

A factor that seemed to be more defining was age. Significant associations were found between the income bracket of the respondents and their age (Figure 4.13), suggesting that the younger respondents had the lower incomes ($\chi2=179.446$; df=8; $P<0.001$). When looking at the riding related habits of the different age groups it can be said that the younger respondents were more likely to ride daily, whereas the older riders would ride several times per week with the middle aged being more likely to be the occasional once a week riders or ride several times per week ($\chi2=28.536$; df=8; $P<0.001$). Show jumping and eventing was most likely participated in by those under 25 with the 25 to 44 year olds being more likely to ride in a riding club and the over 45 year olds being dressage or leisure riders ($\chi2=38.003$; df=10; $P<0.001$; Figure 4.14). When it comes to access to a horse those 25 years and over were more likely to own or loan a horse, with those under 25 likely riding in a riding school, sharing a horse, riding for other people or as part of their job ($\chi2=24.020$; df=8; $P<0.01$). This also meant that they would be riding more horses with older riders being more likely to ride just one horse per week ($\chi2=14.943$; df=4; $P<0.01$). Younger riders would also be more likely to keep their horses on a DIY basis with older riders more likely to utilise grass livery ($\chi2=21.937$; df=8; $P<0.01$). They were also more likely to receive riding tuition ($\chi2=6.104$; df=2; $P<0.05$) more regularly ($\chi2=27.784$; df=8; $P<0.01$). Older riders (25 years and over), on the other hand, were more likely to engage in other activities to further their riding skills such as watch Masterclasses ($\chi2=24.128$; df=2; $P<0.001$), read books ($\chi2=7.064$; df=2; $P<0.05$) and other things ($\chi2=6.078$; df=2; $P<0.05$) with those over 25 doing off-horse exercise ($\chi2=16.763$; df=2; $P<0.001$). When it comes to exercising habits aside from riding those under 45 would be more likely to go running ($\chi2=22.630$; df=8; $P<0.01$), whereas those over 25 would be more likely to participate in Pilates or yoga ($\chi2=34.175$; df=8; $P<0.001$). Under 25 year olds were more likely to engage in off-horse exercise as a method of transport ($\chi 2=11.192$; df=2; $P<0.01$) and all under 45 as an alternative hobby to riding ($\chi 2=7.114$; df=2; $P<0.05$). The older riders were more likely to use off-horse exercise as a way to keep fit ($\chi 2=7.788$; df=2; $P<0.05$), improve postural faults ($\chi 2=13.388$; df=2; $P<0.001$), maintain musculo-skeletal suppleness ($\chi 2=12.316$; df=2; $P<0.01$) or to improve their riding ($\chi 2=13.007$; df=2; $P<0.001$). The over 25 year olds were more likely to believe that off-horse exercise has an impact on their riding ($\chi 2=14.473$; df=2; $P<0.001$, Figure 4.15) and those 45 and over were most likely to participate in it ($\chi 2=16.946$; df=2; $P<0.001$).

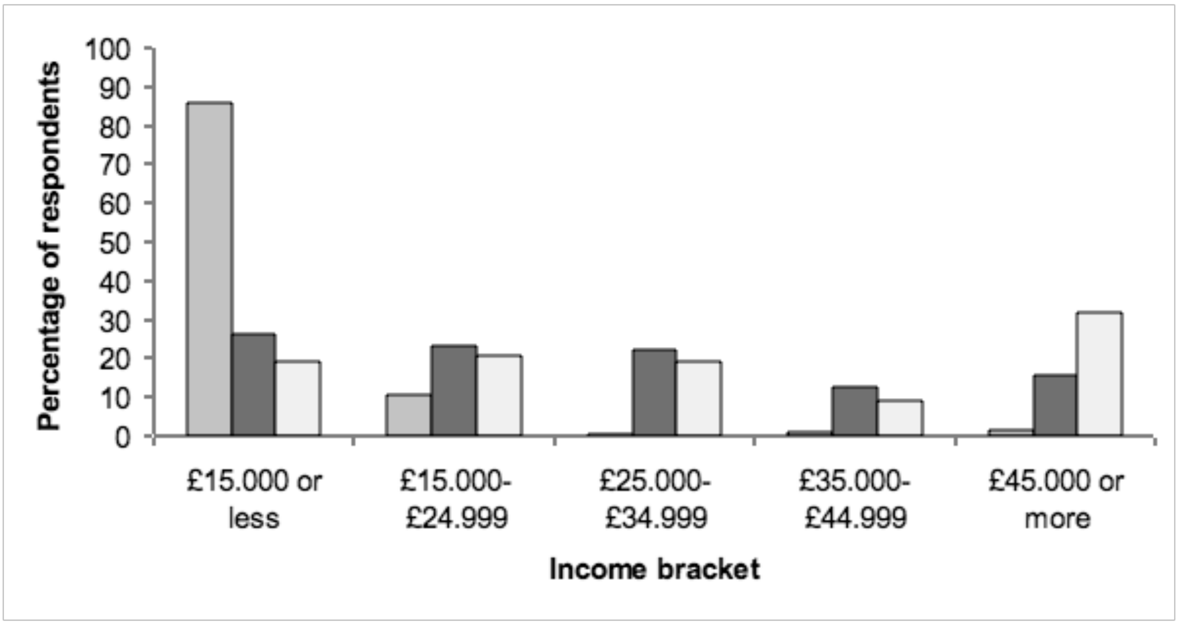

Figure 4.13: Significant association between age group and income bracket of respondents. The light grey bars represent those 16-24, the dark grey bars represent the 25 to 44 year olds and the white bars are representing those 45 and over.

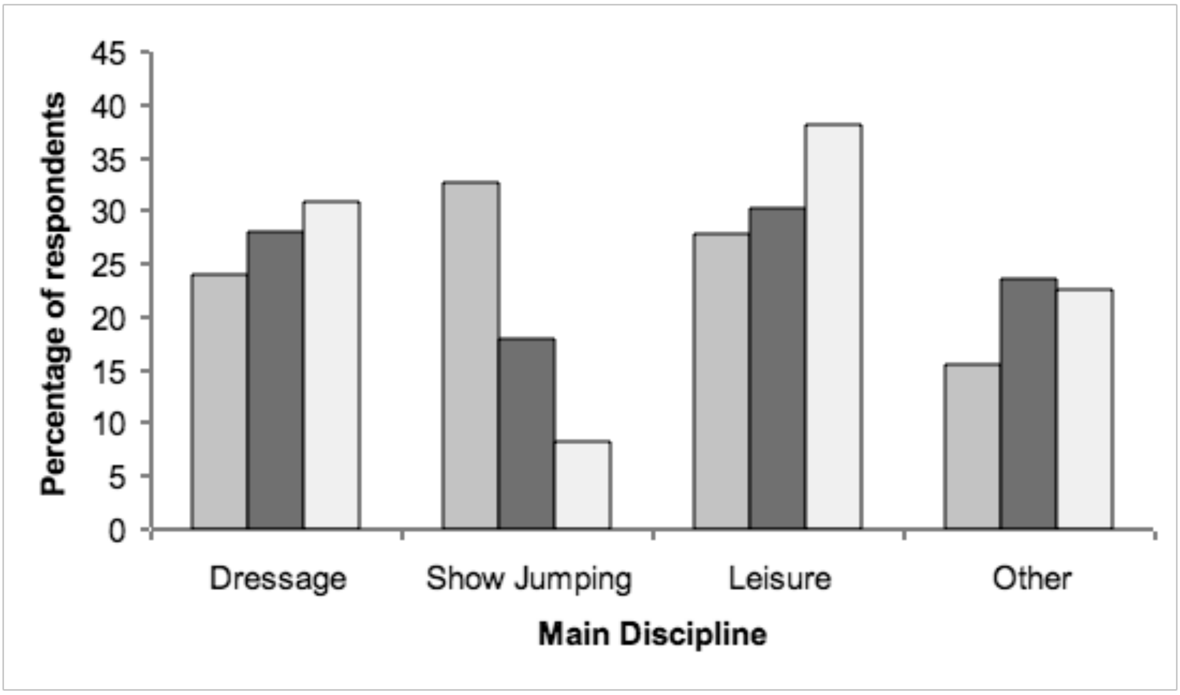

Figure 4.14: Significant association between age group and main discipline of respondents. The light grey bars represent those 16-24, the dark grey bars represent the 25 to 44 year olds and the white bars are representing those 45 and over.

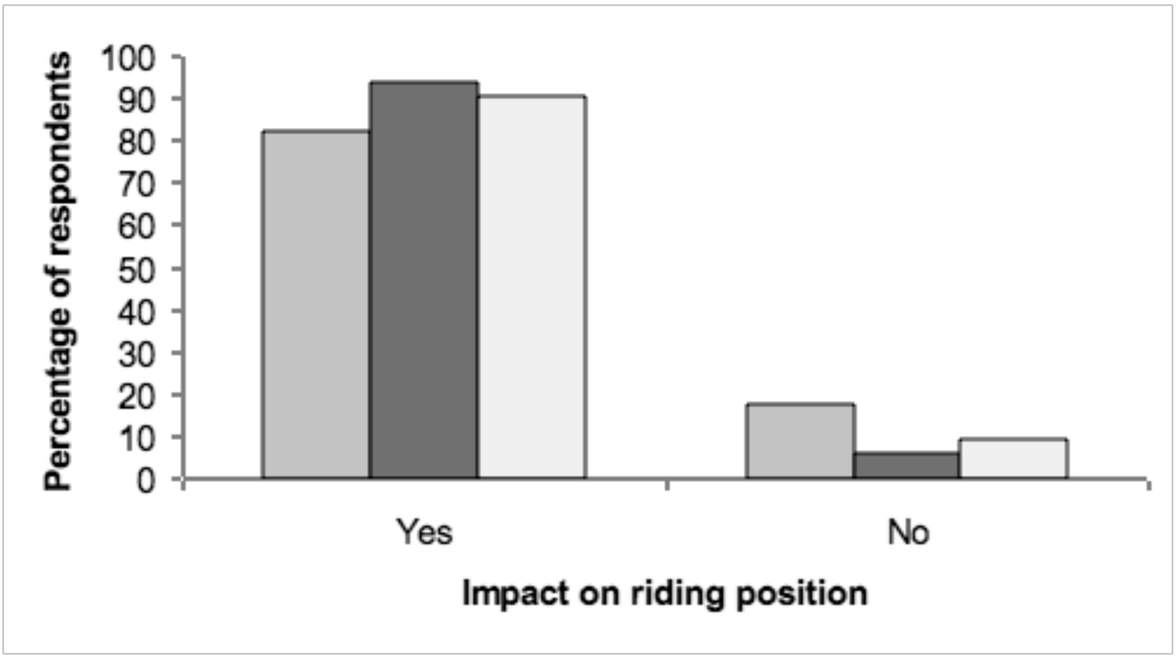

Figure 4.15: Significant association between age group and whether or not the respondents believe that fitness has an impact on their riding. The light grey bars represent those 16-24, the dark grey bars represent the 25 to 44 year olds and the white bars are representing those 45 and over.

Income groups seemed to be another factor that had considerable influence on other variables. Apart from the previously mentioned demographical association with age it seemed to also have an impact on the riding habits of the respondents. Dressage riders were most likely to earn £35.000 and more with show jumpers being most likely to earn less than £15.000 or between £25.000 and £45.000. Leisure riding was most common in those earning up to £35.000 and other disciplines were most likely to be participated in by those earning £15.000 and more ($\chi2=22.730$; df=12; $P<0.05$). Affiliation status seemed to also be associated with income, where those in the highest income bracket were most likely to be competing affiliated above BD Medium/BSJA Foxhunter/BE Novice. Those with the lowest income were most likely to be recreational hackers or unaffiliated up to BD Novice and equivalents. Income brackets between £25.000 and £45.000 were most likely to be competing affiliated up to BD Elementary/BSJA Newcomers/BE100 ($\chi2=26.491$; df=12; $P<0.01$). Those with an income £15.000-£24.999 were least likely to have riding tuition with all other income groups being more likely ($\chi2=13.427$; df=9; $P<0.01$). In addition to this those with an income above £15.000 were more likely to watch masterclasses and such ($\chi2=21.074$; df=4; $P<0.01$) and those with an income of £45.000 and more were most likely to engage in off-horse exercise ($\chi2=10.271$; df=4; $P<0.05$). Additional exercise was carried out as a method of transport primarily by those with an income of £15.000 and less whereas those with an income over £15.000 were more likely to exercise to improve their aerobic fitness ($\chi2=11.689$; df=4; $P<0.05$) and those above £25.000 to keep fit in terms of core stability, balance and flexibility ($\chi2=9.747$; df=4; $P<0.05$). Those earning above £15.000 were also more likely to believe that off-horse exercise had an impact on their riding ($\chi2=11.955$; df=4; $P<0.05$) as well as actually participating in it ($\chi2=10.562$; df=4; $P<0.05$). Most likely to attend an exercise class specifically tailored to equestrians were those earning £25.000 and above ($\chi2=43.508$; df=16; P<0.001; Figure 4.16) with those above £35.000 spending the most money on fitness ($\chi2=27.369$; df=16; P<0.05).

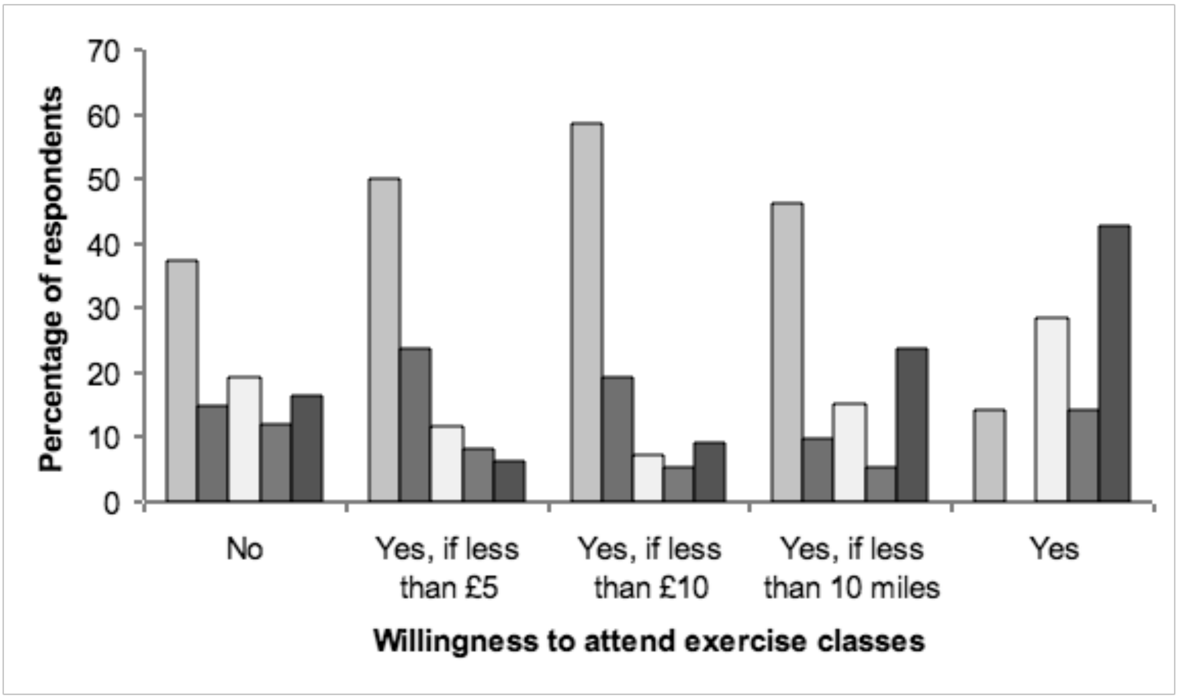

Figure 4.16: Significant association between annual income and their willingness to participating in an exercise class tailored to equestrians. The light grey bars represent those earning less than £15.000, the dark grey bars represent those earning £15.000-24.999, the white bars represent those earning £25.000-£34.999, the medium grey bars represent those earning £35.000-£44.999 and the black bars represent those earning £45.000 and over.

When it comes to the different disciplines dressage riders would most likely own/loan their horses, ride for other people or ride as part of their job for four or more hours per week. They would be most likely to ride just one horse, which would be kept at Part or Full livery. The possibility of them having riding tuition would be highly likely ranging from once monthly to several times per week. It would also be highly likely that they would participate in other activities to further their riding skills such as watch masterclasses or participate in off-horse exercise (Figure 4.17), likely considering themselves advanced in their confidence and willingness to take risks. They would be highly likely to engage in Pilates or yoga, but less likely to participate in team sport.

Off-horse exercise would less likely be considered an alternative hobby, but more likely a means to improve musculoskeletal suppleness and improve their riding. Strong agreement with off-horse exercise as an important part to improve riding performance would be expected (Figure 4.18). The show jumper would most likely ride 6+ hours on 2-3 horses that they own/loan or ride as part of their job. Their horses would be kept in DIY or Full/Part livery. Likely considering themselves experienced/professional in their risk-taking levels they would most likely compete affiliated across all levels. Lessons would be highly likely several times per week to fortnightly. Apart from that the show jumper would be less likely do anything to further their riding including off-horse exercise. They would be less likely to do Pilates or yoga and more likely to participate in team sport several times per week considering it an alternative hobby to riding; however, they would participate in off-horse exercise particularly to improve their riding. Their agreement with off-horse exercise as an important part to improve riding ranges from agreeing to strongly disagreeing, but they are less likely to strongly agree. Leisure riders would be most likely to ride 2-3 hours per week on one shared or riding school horse that is likely kept at grass livery. They consider themselves novice to intermediate in their confidence and are not likely to have riding lessons or particularly do anything else to improve their riding either. They are not likely to participate in much exercise off-horse and when they do they would most likely consider it an alternative hobby to riding. When considering off-horse exercise as a way of improving riding performance they range from slight agreement to indifference. Those of other disciplines are most likely to ride between 2 and 5 hours per week on horses that they ride for other people or as part of their job. Most likely riding 2-3 horses per week they would ride recreationally or compete unaffiliated and consider their confidence level as intermediate of experienced. Their horses are mainly kept at grass livery and they don't tend to have riding tuition and if so only frequently. They do like to watch masterclasses, but are not likely to exercise to improve their riding. Occasionally they like to participate in team sport as an alternative hobby to riding and to maintain musculoskeletal suppleness. They don't particularly see off-horse exercise as an important part to improve horse riding, but also do not disagree with it. The associations of discipline and other variables are shown in Table 4.10.

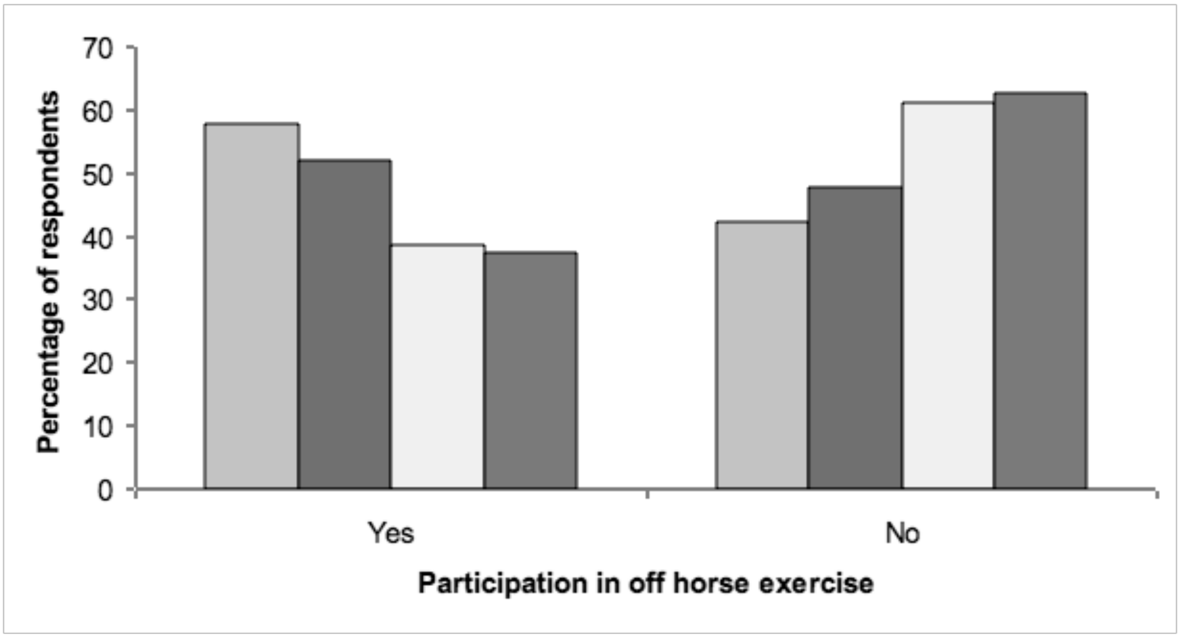

Figure 4.17: Significant association between discipline and whether the respondents participate in off-horse exercise particularly to improve their riding. The light grey bars represent dressage, the dark grey bars represent show jumping, the white bars represent leisure and the medium grey bars represent other disciplines.

Table 4.10: Significant associations of respondents discipline and other variables.

	χ^2	**df**	**Asymp. Sig. (2-tailed)**
Hours riding per week	97.276	12	0.000
Access to a horse	22.579	12	0.032
Horses per week	67.623	6	0.000
Livery type	42.677	12	0.000
Confidence level	120.127	12	0.000
Affiliation status	165.573	9	0.000
Riding tuition	55.051	3	0.000
Tuition frequency	84.667	12	0.000
No activity to improve riding	9.643	3	0.022
Masterclasses, etc.	19.370	3	0.000
Off-horse exercise	14.506	3	0.002
Do Pilates/yoga	24.440	12	0.018
Team sport	35.471	12	0.000
Alternative hobby to riding	13.156	3	0.004
Musculoskeletal suppleness	14.526	3	0.002
Improve riding	11.115	3	0.011
Participate in sport particularly to improve riding	16.142	3	0.001
Agreement with statement	21.904	12	0.039

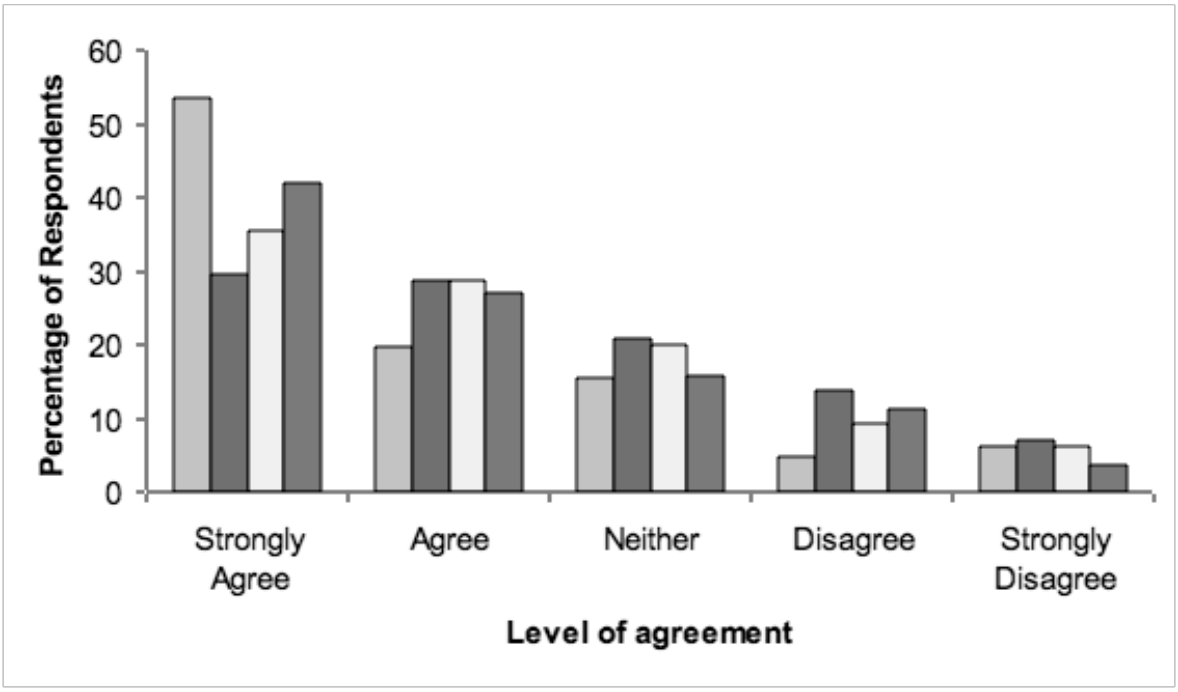

Figure 4.18: Significant association between discipline and the respondents level of agreement with exercise as an important part of improving their riding. The light grey bars represent dressage, the dark grey bars represent show jumping, the white bars represent leisure and the medium grey bars represent other disciplines.

The respondents that received riding tuition were most likely keep their horses at DIY or Full/Part livery ($\chi2=24.789$; df=4; $P<0.001$) and were very likely to ride two or three horses per week ($\chi2=11.576$; df=2; $P<0.01$). Their likelihood of riding 4+ hours per week ($\chi2=32.527$; df=3; $P<0.001$) as well as engaging in other activities to improve their riding was also found to be greater than those who do not receive riding tuition ($\chi2=21.258$; df=1; $P<0.001$). How the horse was kept was also associated with riding frequency with those who kept their horses on DIY, part and full livery likely riding more hours per week than those who kept their horses at grass livery or who kept no horse at all ($\chi2=119.127$; df=16; $P<0.001$). Along with the very beginners those competing unaffiliated or affiliated up to BD Medium and equivalents were more likely to receive riding tuition than the recreational and top riders ($\chi2=42.997$; df=13; $P<0.001$). A significant association was also found between the access to a horse and the amount of horses ridden per week with those riding as part of their job being most likely to ride four or more horses ($\chi2=91.943$; df=8; $P<0.001$).

Posture, flexibility and balance was most likely believed to be the main factor influencing riding performance by those who do not receive riding tuition as opposed to core stability and cardiovascular endurance by those who did ($\chi2=11.608$; df=4; $P<0.05$). The second group was also more likely to participate in off-horse exercise to improve their riding ($\chi2=18.075$; df=1; $P<0.001$; Figure 4.19) as well as being willing to participate in exercise classes tailored to the needs of the equestrian ($\chi2=13.847$; df=5; $P<0.05$; Figure 4.20).

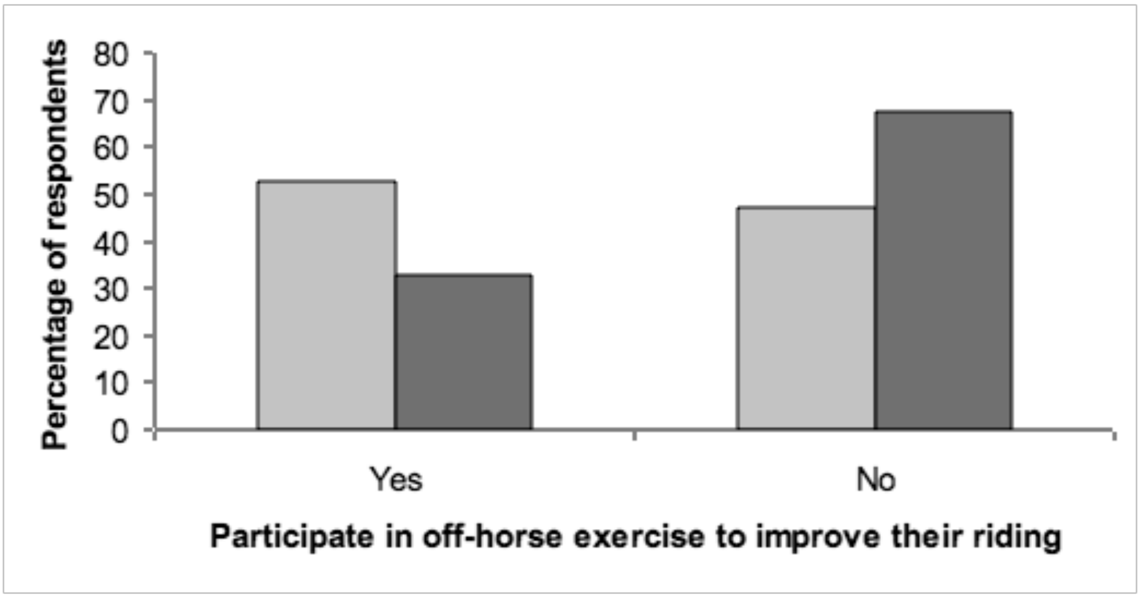

Figure 4.19: Significant association between those that receive riding tuition and whether or not they participate in off-horse exercise particularly to improve their riding. The light grey bars representing those who receive riding position, and the dark grey representing those who do not.

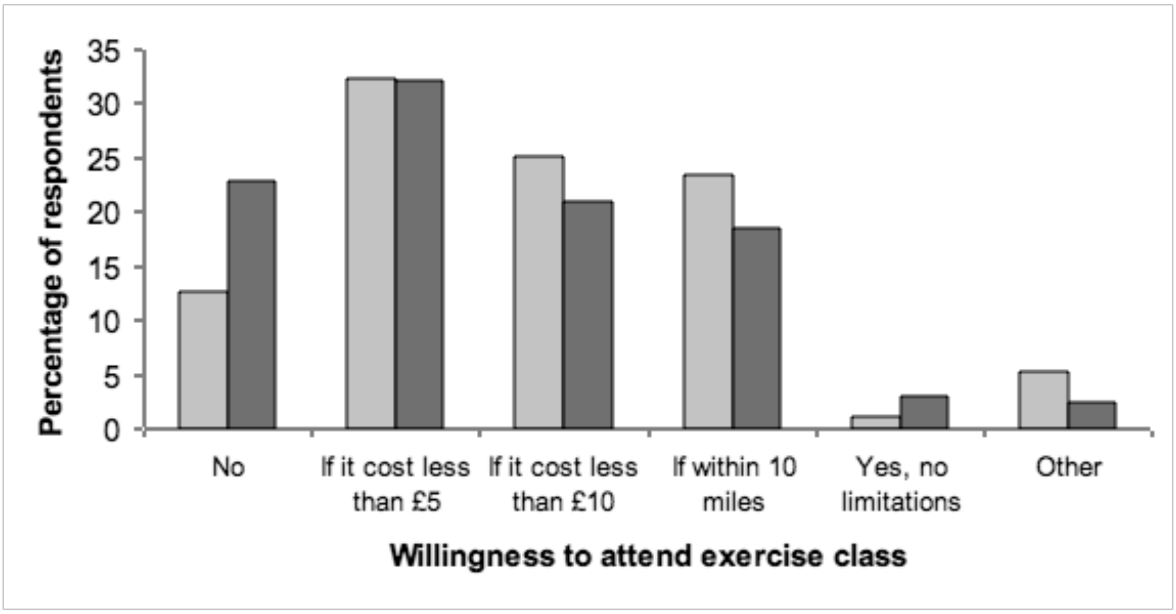

Figure 4.20: Significant association between the willingness to attend exercise classes tailored to equestrians and whether or not they receive riding tuition. The light grey bars representing those that receive riding position and the dark grey representing those who do not.

Respondents that stated that they engage in activities outside of riding and receiving riding tuition to improve their riding were found to be more likely unaffiliated or those competing at the top level ($\chi 2=9.762$; df=3; $P<0.05$). The likelihood of attending exercise classes tailored to them was higher for this group (Figure 4.21) and they were most likely to be concerned about the distance as a limitation than money, whereas those who do nothing apart from riding would likely be interested in off—horse exercise classes if the cost was kept low ($\chi 2=33.765$; df=4; $P<0.001$). They were also most likely to spend less money on fitness per month, if any ($\chi 2=41.254$; df=4; $P<0.001$).

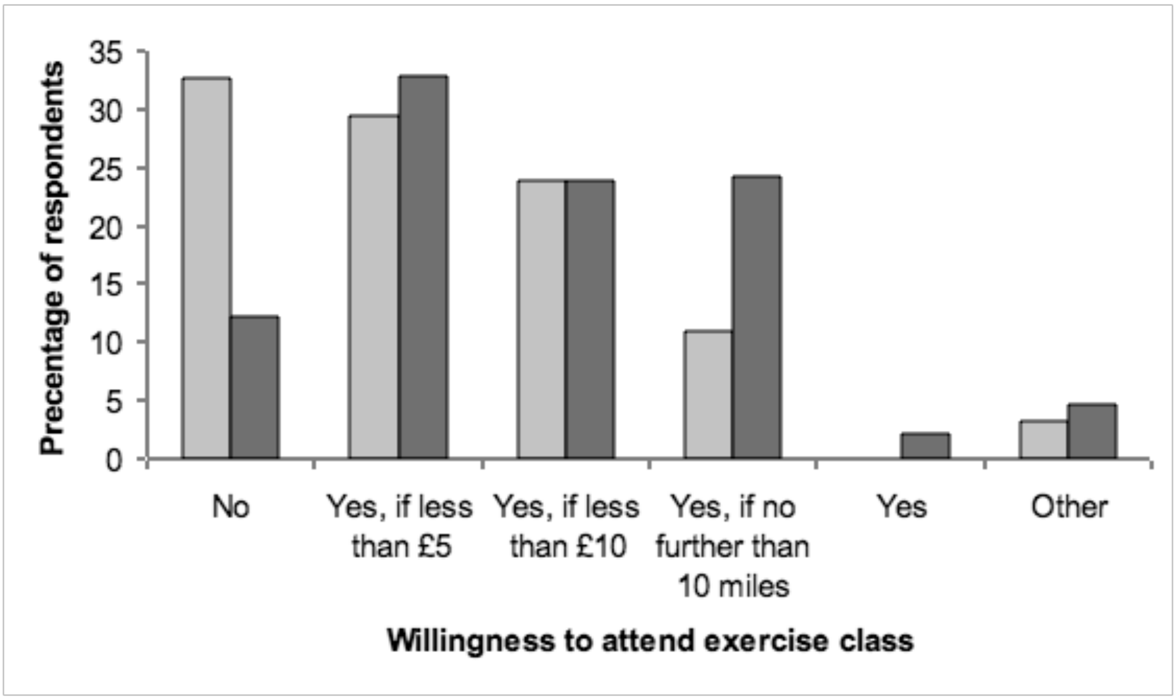

Figure 4.21: Significant association between whether or not the respondents engage in secondary activities to improve their riding and the willingness to attend exercise classes tailored to equestrians. The light grey bars representing those that do nothing to improved their riding and the dark grey representing those who do.

If the respondents believed that off-horse exercise made an impact on their riding they would be more likely to exercise, particularly to improve their riding ($\chi2=41.245$; df=1; $P<0.001$). They would also be more likely to think that core stability, cardiovascular endurance or flexibility have the highest influence on their riding position. Those who did not believe that off-horse exercise affects riding position who would be more likely to believe that balance and posture have the greatest impact on riding position ($\chi2=17.926$; df=4; $P<0.001$; Figure 4.22). They would also be more likely to agree with off-horse exercise being in important part to improving riding position because of the influence horse and rider have on each other ($\chi2=50.590$; df=4; $P<0.001$) and would be prepared to spend more money on fitness per month ($\chi2=17.588$; df=4; $P<0.001$). Off-horse exercise would likely be a means to improve fitness parameters.

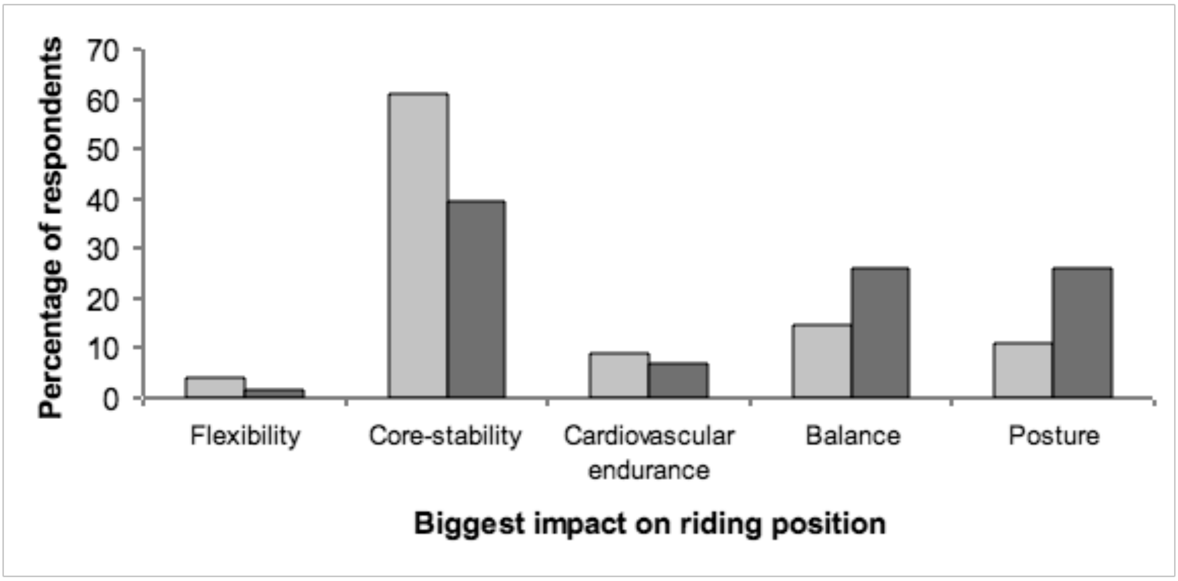

Figure 4.22: Significant association between whether or not the respondents believe that off-horse exercise impacts their riding and which fitness parameter they believe impacts it most. The light grey bars representing those that do believe exercise impacts riding and the dark grey representing those who do not.

The respondents that would participate in off-horse exercise particularly to improve their riding would be more likely to do Pilates or yoga than others ($\chi2=120.221$; df=4; $P<0.001$). They would be more likely to partake in secondary exercise because they want to improve their fitness parameters and would likely be willing to spend more money on fitness ($\chi2=38.873$; df=4; $P<0.001$). As previously mentioned they would be highly likely to be of the older age group and higher income bracket as well as most likely to be dressage riders or show jumpers. Other associations found were: tuition frequency with those exercising being likely to receive more regular riding tuition ($\chi2=16.596$; df=2; $P<0.01$) and their place of residence with those outside of the UK being more likely to participate in exercise to improve their riding ($\chi2=16.039$; df=8; $P<0.05$; Figure 4.23).

Gender was not associated with whether or not respondents would participate in off-horse exercise particularly to improve their riding.

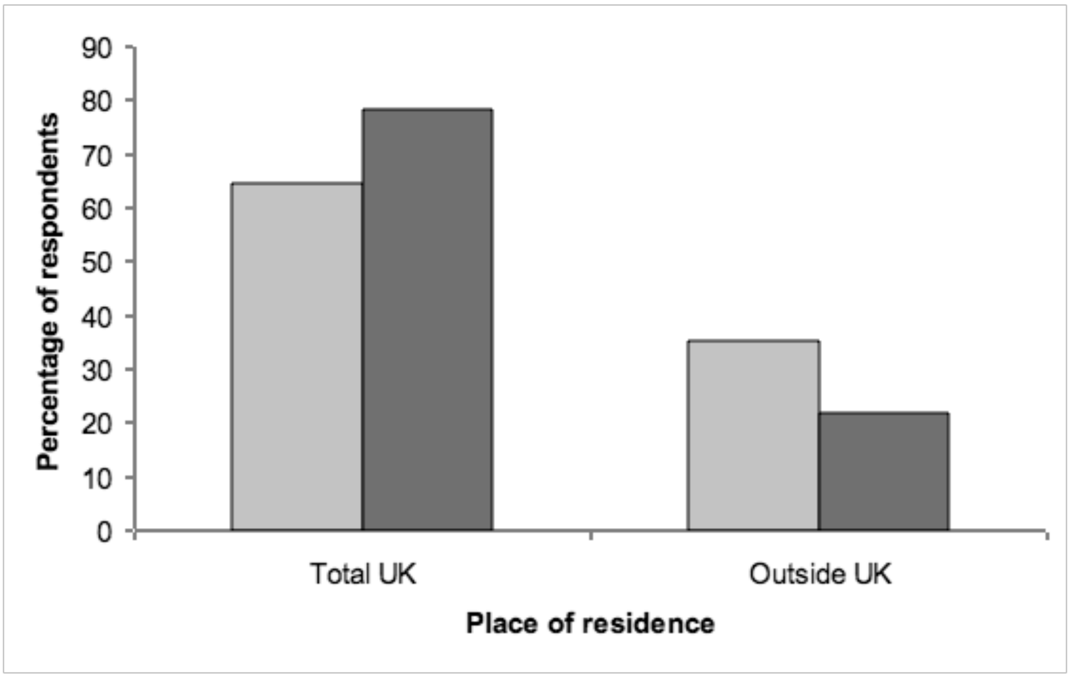

Figure 4.23: Significant association between whether or not the respondents participated in off-horse exercise particularly to improve their riding and where they live (The different UK places of residence were added as otherwise the graph would have been too big. The tendencies off all were the same as of the total). The light grey bars representing those that participate in off-horse exercise to improve their riding and the dark grey representing those who do not.

Other interesting findings were that those in agreement with off-horse exercise being important to riding ability would be more likely to engage in other activities to improve their riding ($\chi 2=27.997$; df=4; $P<0.001$) as well as being likely to spend more money on fitness per month ($\chi 2=41.453$; df=16; $P<0.001$). They also generally thought that core stability has the greatest impact on riding position ($\chi 2=27.825$f=16; $P<0.05$).

4.5 Discussion

The research set out to investigate the exercise habits of equestrians and how important they perceived off-horse exercise to be in improving riding position. It was also investigated what factors would make horse riders more likely to acknowledge off-horse exercise as an important aspect of improving riding position and what factors would limit participation in off-horse exercise.

Demographic information of participants (Table 4.1)

When looking at the gender distribution for the questionnaire it can be said that most respondents were women. Comparing this to the membership percentages of BD, BSJA and BE which average at roughly 14% (Dashper, 2013) and considering that women are considered more likely to take part in questionnaires (Jackson *et al.*, 2001) the results of this study can be considered in line with what could be expected. Age distribution was found to be similar to that of the BETA survey 2010/11. At 48% (37.98% in this study) nearly half of respondents and thus also the largest group were under 25 years old, 32% (43.51%) being between 25 and 44 years and 20% (18.32%) being 45 years or older. When taking into account that this questionnaire was partly distributed through the international society of equitation sciences (ISES) it could be explained that the respondents' ages in this survey are slightly higher because of the distribution channels.

The large group of respondents with an income under £15.000 annually does not seem to comply with the average annual income (Office for National Statistics, 2013), but could be explained with the high amount of 16-24 year olds that partook in the survey and may not have an income yet at all. The chief income in the BETA survey was more evenly spread across the groups, though the results of this survey cannot be directly compared to that of the BETA survey as the income of the respondent was questioned as opposed to the socio-economic group of the primary earner of the household.

Geographical distribution of respondents is also similar to that found by the BETA survey with the difference that Northern Ireland and outside UK residences were included resulting in lower percentage figures for the majority of regions. The high number of respondents from the south (34.9% as opposed to 23% in BETA survey) could be explained with the author's contacts as well as Facebook pages through which the survey was advertised. Again, the distribution through ISES is likely the key factor in generating such a high response rate of those residing outside the UK with affiliates across the world.

Riding habits

Riding experience seems to be in line with age groups accounting for those that started to ride later in life. Looking at the amount of hours respondents ride per week this seems to be in line with the high amounts of horses that are owned/loaned (Figure 4.1). Because most horses are kept in DIY livery it could be assumed that they are stabled at least at night and thus owners exercise them most days (Figure 4.2). At an average riding session of an hour (Deutsche Reiterliche Vereinigung, 1996), that would add up to six hours per week or more. Those that ride less than this could be assumed to be accounted for by those horses kept on grass livery or are ridden at a riding school, which is supported by the data as those that do not keep horses and those that keep their horses on grass livery had a higher than expected count for less hours per week and lower than expected count for more hours per week with those that kept their horses on DIY, full or part livery being the opposite. Because most horses are kept at DIY liveries it can also be assumed that the owners/carers of these horses get a basic workout each day by tending to their horses. With most respondents riding between one and three horses per week it is likely to be the professionals or those riding in a riding school that ride four or more horses. This is again backed up by data with a significant association between access to horse and horses ridden per week. Those that ride as part of their job had an expected count for riding 4 or more horses of 4.9 with an actual count of 22.

The distribution of discipline seemed to have been a little bit difficult (Figure 4.3). The high amount of international responses was not anticipated; thus, the questionnaire was mainly designed for the UK audience with the main disciplines being dressage, show jumping, eventing and leisure riding and riding club activities. The reason for the other group being so large could therefore be explained with the various types of western riding and natural horsemanship, both of which are highly popular in the US and Australia. Roughly two thirds of respondents state that they receive riding tuition, with most of them receiving help with their dressage. Because this is the basis of all disciplines (Auty, 2006) these results are not surprising. Again the high amount of other answers could be explained with the high amount of other disciplines the respondents participate in (Table 4.2). Secondary activities besides riding tuition were highly participated in with only few (17.5%) not doing anything to improve their riding. Most likely respondents would read books and riding theory (66%) or watch masterclasses (50.6%). Even though off-horse exercise was not listed as an option respondents listed it as other activity as a response. It could be argued that this would not have been the case if respondents had not known the nature of the questionnaire. They did not know the next set of questions that were coming and that this particular question would come up. If this response had not been wanted the directive should have stated not to include riding tuition in this answer. The results of how many did exercise were also not significant because most respondents did not have this possible response and did not think of it on their own (Figure 4.4).

The remaining responses that were classed as other could not be analysed on their own because of the minimal frequency (Balakrishnan, 2012). Many respondents classed themselves as unaffiliated or recreational, which considering the cost of affiliated competition and the income brackets would seem to make sense. Level of schooling at home was slightly raised as expected and most respondents considered themselves intermediate to experience in their risk-taking willingness and confidence (Figures 4.5-4.7 and Tables 4.3-4.5).

Exercise habits and perceived impact of exercise on horse riding

When it comes to additional exercise being undertaken it is not surprising that walking is the most participated in activity closely followed by running. Going to the gym was not widely participated and this is hypothesized due to time and financial restriction of looking after horses (Figure 4.8 and Table 4.6). It would have been interesting to ask opinion on to what degree respondents feel yard work could be considered a good work out. These activities were participated in mainly to stay physically fit and to lose weight (Figure 4.8). Less than half of the respondents stated that they participated to improve riding (Table 4.7). The average amount spent on fitness per month and the high proportion of respondents who spend no money at all could be considered to support the previous statement of financial restrictions that are applied when keeping horses. When asked about whether or not the respondents believed that off-horse exercise would make an impact on their riding the vast majority (88.9%) said yes (Table 4.8). This answer could be slightly biased because of the title of the questionnaire. There is a possibility that those who are convinced that off-horse exercise makes a difference in riding would be more likely interested in taking part in the survey. It is widely known that the training for most other sports is supplemented by strength training, cardiovascular training, or what might be appropriate for the given discipline (Reilly, 2006). Footballers, for example, do not only train on the pitch, but also spend several hours per week with strength training, cardiovascular conditioning, etc. (Hides *et al.*, 2012). It has also been suggested in several studies that certain fitness parameters have a positive impact on horse riding (Wilkinson and Graham, 2006, Sudhoff, 2010, Boden and Randle, 2012).

The survey found that those who believe that off-horse exercise would make no difference to horse riding were more likely to be Show jumpers or Eventers with dressage riders being more likely to believe in the importance of off-horse exercise. This could be explained through the difference in riding position between show jumping and eventing as opposed to dressage, where an ideal seat is more necessary for success. It could be argued that publicising the implications of poor fitness could have on both horse and rider (de Cocq *et al.,* 2004) needs to be of priority to educate on the benefits in off-horse exercise not only to the rider but also the horse's welfare This is only supported by the fact that out of the 88% that know that off-horse exercise would influence their riding only 46.6% actually practice it. Out of those that do exercise to improve their riding the majority aims to improve their riding position while some also aim to delay fatigue and reduce being out of breath. Core stability seems to be commonly believed to have the biggest effect on riding position (Figure 4.9). Specialised exercise classes for equestrians seem to be of interest if the conditions are right (Figure 4.10). Concerns seem to lie primarily with cost, which could again be due to the fact that horse riding is generally expensive (BETA, 2011). It can generally be said that the majority of respondents perceive off-horse exercise as an important part of improving riding position (Figure 4.11). As previously mentioned this could well be influenced by the nature of the survey; however, the general consensus seems to be accurate nonetheless.

Associations between responses

Considering the results of the chi-squared associations a few relationships seem to stand out immediately. Dressage riders seem to have the highest regard for off-horse exercise to improve their riding and are also most likely to attend exercise classes for riders (Figures 4.17 and 4.18). This could be explained due to the dressage seat being highly reliant on good core stability (Wilkinson and Graham, 2006; Sudhoff, 2010). To communicate the very specific aids to achieve precision in movements requires a high amount of body control, which can only be achieved through strong postural muscles that allow the rider to maintain a balanced seat in rhythm with the horse’s movements (Dietze, 2003). The dressage riders were also generally older and the older riders were also more likely to participate in off-horse exercise (Figures 4.14 and 4.15). The older age could mean less general fitness like flexibility, (Huang *et al.*, 1998) because of which he would be more reliant on the exercise. The older riders were also associated with a greater annual income, which may be why they would be more likely to pay for exercise classes as opposed to the younger and less earning adults who are more likely to go for a run (Figure 4.13). On the other hand, it could also be assumed that the older rider has more experience and is more aware of the requirements of a stable and balanced seat. Being older was also associated with dressage, but it can be assumed that this is not the only reason because he is more likely to exercise off-horse since being an older rider was also associated with leisure riding. Show jumping and eventing were more participated in by the younger riders, which could explain the lower regard for off-horse exercise. A show jumping round lasts only just over a minute, whereas a dressage test tends to take several minutes (Roberts *et al.*, 2009). Show jumpers are therefore less likely to worry about being able to maintain position for a longer period of time without fatigue, when short bursts of energy are required. In line with younger riders being more likely to go running this could seem like more discipline specific training. Those of a higher income group were likely to attend specific exercise classes regardless of price or the traveling distance, whereas those of a lower income bracket were more likely to not be interested in an exercise class or be more concerned with the expense (Figure 4.16). The expensive nature of horse riding explains this. It can also be said that those who engage in other activities to further their riding, such as reading riding theory are more likely to receive riding tuition as well as attend exercise classes (Figure 4.21). Whether this is due to the increased level of commitment or the better awareness cannot be said with certainty and it would be worth investigating the reasons why.

Reasons for exercise could also be discussed with those earning less being more likely to do exercise as a method of transport. On the other hand, those with a higher income were more likely concerned with their fitness. Knowing that those earning more tended to be older could come down to the need to exercise to maintain a healthy fitness level or to the better awareness of the links between better fitness and welfare and performance. Core stability and cardiovascular fitness being considered most important to riding ability is highly likely linked to the fact that show jumpers and dressage riders are most likely to receive riding tuition. The show jumper would need cardiovascular fitness and the dressage rider the core stability, though these assumptions are not supported by the results.

Why those outside of the UK were more likely to participate in off-horse exercise is a question that cannot be answered with certainty (Figure 4.23). A possible reason could be that those outside of the UK would have likely received the link to the questionnaire through ISES as this was the only obvious way of distribution outside of the UK. Because of the nature of ISES being a group of equitation scientist the level of knowledge and regard for the horse's welfare might be the influencing factor that would lead them to participate in off-horse exercise having heard presentations at conferences and read publications in the journal. Though this seems to make a lot of sense it would be interesting to investigate this matter further as to date this theory is based on speculation.

4.6 Conclusion

The general consensus (89% of the sample) of this study was that off-horse exercise would have an impact on riding position. Most respondents believed that this was due to an improvement in core stability. Dressage riders can be considered to have the highest regard for off-horse exercise because they were most likely to participate in it. They also most agreed with the degree of importance, which is explained through the higher isometric muscle usage in this discipline to achieve the illusion of the static, ideal position (Ritter, 2013). The perception of the respondents seems to be in line with previous studies that have found core stability training to have a positive effect on riding position (Terada *et al.*, 2004; Wilkinson and Graham, 2008; Sudhoff, 2010; Boden *et al.*, 2014). Another finding of this research is that the older adults are more likely to participate in off-horse exercise classes. They are also more likely to pay for exercise classes, whereas younger adults are more like to exercise on their own. The reasoning for this is likely due to the difference in income as the older were associated with a higher annual income. The older riders may also have a better awareness of the benefits of off-horse exercise through experience. Those outside the UK also placed more importance on off-horse exercise, which was explained through the distribution channel of the survey with the more educated in equestrian science being the ones responding to the survey from abroad. It can be said that those investing more into time and effort in their riding through educating themselves further through tuition, masterclasses and reading would also be more likely participate in off-horse exercise. Further studies into the reasons to why certain groups would be more predisposed to engage in off-horse exercise would be recommended. This would give insight into which would be the best ways to educate on the benefits of off-horse exercise as well as how to best target different demographic groups from a marketing point of view. The key finding of this research is that most participants believed that off-horse exercise and therefore their general fitness would help in improving riding performance. Going forward this research project will investigate whether these perceptions can be considered factual. For this the characteristics of riding position and the effect of fitness parameters on the rider’s seat will be explored.

Chapter 5

A cross sectional study investigating the effects of fitness parameters on riding position

Parts of this research study were presented at the 8th International Equitation Science Conference, Edinburgh (Sudhoff, J. and Gowers, I. (2012) ‘An investigation of fitness parameters and their impact on riding position in the equestrian’, Conference Proceedings, 111.)

5.1 Introduction

In the previous study the view of the equestrian population on the links between fitness and riding position as well as the perceived importance of off-horse exercise on riding position were investigated. The results showed that the vast majority of riders believe that core strength would have the biggest impact on their seat. 88.6% of riders also believed that fitness has an impact on their riding position, but only 46.6% of riders participated in exercise to improve their riding position. The older group of riders was also more likely to participate in off-horse exercise. Having gained this insight it was then interesting to know if there were actual links between fitness and the rider's seat and if the links were those that were expected by the equestrian population.

The pelvis is commonly accepted to be the foundation of the rider's seat (Dietze, 2003), which has to temporally and spatially adapt to the horse's movement to facilitate efficient and precise communication between horse and rider (Peham *et al.*, 2010). It is also fundamental to good postural control with pelvic instability increasing postural sway of the lower trunk region (Boehme, 1988; Reid, 1996).

Recent research suggests that the seat of the advanced rider differs from that of a novice rider in angular nature (Schils, 1993) as well as muscular activity (Terada, 2000; Terada *et al.*, 2004; Probin, 2014). Herein the novice rider displays a larger forward flexion of the trunk as well as more noise in muscular activity not being able to gauge movement correctly. Muenz *et al.* (2014) also found that the more advanced rider exhibits a more anterior pelvic tilt along with a more balanced base in comparison to a more posterior and right lateral pelvic tilt supporting previous findings that suggest riding positions vary with skill and experience (Schils, 1993; Terada, 2000). Nevison and Timmis (2013) pre intervention testing results agree with previous research suggesting natural asymmetry in humans (Corballis, 1989) as well as horse riders (Symes and Ellis, 2009). Post physiotherapy treatment targeting the pelvis in experienced horse riders suggested that laterality could be attenuated in the short term. Apart from resulting in poor communication an unresolved unbalanced seat could also lead to musculoskeletal asymmetry and potentially injury in both horse (Dyson, 2000; Nadeau, 2006) and rider (Quinn and Bird, 1996). Based on these findings it could be assumed that a balanced seat could improve the horse-rider dyads performance as well as health.

This particular study is set out to investigate riding position and the differences between more and less experienced riders as well as the effect of a number of fitness components on riding position. Because core strength and flexibility are said to have an impact on riding position the differences in riding position with those of higher and lower scores will be compared. For this study, the average balancing score of 30 seconds was used as the cut-off point between those with better and not so good dynamic standing balance. Those with greater and lesser flexibility were split by the mean. The differences in riding position between age groups will also be investigated to gain an understanding of why they would feel a greater need for the off-horse exercise to improve their position.

5.2 Aims and Objectives

Research Aim:

The aim of this study was to investigate the effect of certain fitness parameters on riding position as well as the differences in riding position between those who have more riding experience and those with less practice.

Research Objectives:

Objective 1: To gain an understanding of the rider's seat in walk, trot and canter and the differences between the gaits and to compare the angular characteristics and pressure distribution of the seat between the more and less experienced riders.

Objective 2: To establish the general fitness of a cross section of the horse riding community.

Objective 3: To investigate the effect of balance, flexibility, core stability, posture and cardiovascular fitness on riding position.

Objective 4: To relate the research findings of equestrian athletes to studies looking at the effect of fitness parameters on performance in other disciplines.

Hypothesis:

There is a significant difference in riding position between more and less experienced riders and fitness parameters do have a significant influence on riding position.

5.3 Methodology

Thirty-eight female riders aged between 18 and 61 years (26.64 ± 11.45 years), weighing from 50kg to 81kg (58.09 ± 9.75kg) who had riding experience from 4 to 48 years (18.28 ± 11.55) were randomly recruited to take part in the cross-sectional study. The specification for females only was due to gender differences in pelvic anatomy (Gray, 1987). Requirement to participation in the study was a minimum of one hour of riding per week. Before the study commenced all subjects gave informed consent and were screened through a Physical Activity Readiness Questionnaire (PAR-Q). All subjects filled in a detailed questionnaire on their demographics, discipline and riding tuition as well as physical activity including any exercise as well as stable duties, etc. Grouping for riding experience was divided into three groups, which were less than 10 years, 10 to 20 years and more than 20 years. This was roughly based on the results of the previous chapter, but also grouped in a way that there would be enough respondents in each group so that statistical analysis was still possible.

Riding position was analysed using a mechanical horse (Racewood Dressage Simulator, 2008) to eliminate variation due to the horse. Even though it had been found to have a lower physiological demand of the horse rider and could only be partially imitate riding an actual horse (Ille *et al.*, 2015) previous validation studies showed that there was no significant difference in angular characteristics of the rider's seat (see Chapter 3.4). Throughout the study a Kieffer dressage saddle (Starnberg, 17") was used. A pilot study had been carried out before the start of the research to ensure all data could be measured and collected in the proposed way, i.e. distance to the camera is satisfactory, the method of measurement is applicable, equipment is suitable, etc. No changes were necessary.

Core strength was measured using a combination of three muscle endurance tests as recorded by McGill (2007). These three tests looked at Flexor, Extensor and Oblique endurance. Balance was measured using the Standing Stork Test on a stability air disk (McCurdy and Langford, 2006). Indicator for both core strength and balance was the time the respective position was held by the subjects. The average balancing score of 30 seconds was used as the cut-off point between those with better and not so good dynamic standing balance. This average balance score is based on the guidelines by the National Register of Personal Trainers. To determine the flexibility of a range of joints in the subjects the Flexitest was used (Araujò, 2004). Those with greater and lesser flexibility were split by the mean of the total available flexibility score. With 16 tests being carried out and the maximum score being 4 the average score would have been 32 which was used as the cut off between good and poor flexibility. This approach was chosen because no guidelines were available what Flexitest scores were considered good or poor. Aerobic fitness was estimated through the means of an Astrand-Rhyming cycle ergometer test. Heart rate was measured on the mechanical horse in the light seat in trot after three minutes to gain an understanding on how aerobically challenging the riders found the task. Ideally aerobic fitness with direct relation to horse riding would have been measured using a portable gas analyser; however, none was available for use in this study.

After a short adaption period on the mechanical horse the subjects were asked to ride the mechanical horse as they would ride an actual horse in walk, trot and canter. There was no acclimatisation to the mechanical horse to ensure the same starting conditions for all subjects. Although GRF forces in walk are too low to observe a change in position due to core stability training (Clayton, 2004) all gaits were recorded in case other fitness parameters would make a difference.

Video clips were recorded on a frame-by-frame basis over four consecutive stride cycles in each gait at a frequency of 50 frames per second. To ensure the same stride cycle was used for analysis the starting point of the mechanical horse with its pelvis at the lower point during the stride cycle was determined. The camera (Canon, MD150, Tokyo, Japan) was set up perpendicular to and at a distance of six metres of the mechanical horse, to allow for the whole body of the rider to be visible on the recordings. The known distance of the base of the mechanical horse was used for calibration purposes. Rider position was analysed digitally using the Quintic Biomechanics Software v.19 (Sutton, United Kingdom).

Circular skin markers were placed on the left side of each rider at the following anatomical parts of the body: the ankle (lateral *malleolus*); the knee (lateral side of the centre of the flat portion of the *condyles* of the femur); the proximal cessation of the thigh bone (greater *trochanter* of the femur); the hip (lateral *iliac crest*); the shoulder (*acromion* process of the *glenohumeral* joint centre); and the head (*orbitale*) (adapted from: Lovett *et al.*, 2004). The angle measurements of the experiment are defined in Section 3.3 and are in dependence on the investigation by Lovett *et al.* (2004) on rider position.

For the pressure recordings a Tekscan pressure mat (Tekscan Inc., South Boston, MA, USA) was used under the saddle on the mechanical horse. To ensure the mat was placed the same every time testing was carried out, markers were attached to both the mat and the mechanical horse for accurate alignment. Before recording the system was calibrated with the weight of each subject that was taken with the same scales immediately before mounting. The recordings of pressure were taken at the same time of the subject being video recorded for positional analysis in walk, trot and canter. No syncing of data was possible due to limitations in equipment. The recordings were then played back and the peak pressure readings, which were recorded in kilopascal (KPa), of four areas (Figure 5.1) were taken. Both anterior readings were added together to establish anterior peak pressure and the same was true for posterior, left and right peak pressures. Peak pressure was chosen as it is commonly used in saddle fit studies and was available from the software kit that was purchased by Writtle College.

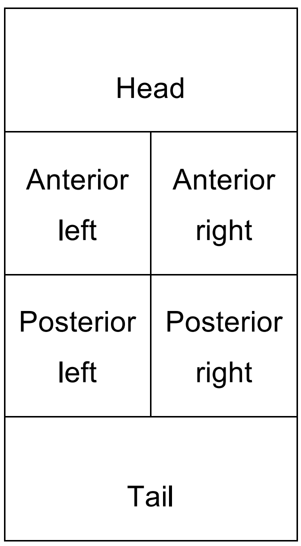

Figure 5.1: Definition of the four separate areas of the pressure mat of which recordings were taken.

The data collected was analysed using the SPSS Statistics version 19.0 (SPSS Inc.; Chicago, IL) computer programme. A Kolmogorov Smirnov Test was carried out to test the data for normal distribution. Because the data was found to be normally distributed and thus parametric, a Paired-Samples T-test was applied. Differences between groups were investigated using the independent samples T-test or One-Way ANOVA. To test for interaction between the data Pearsons two tailed bivariate correlations were used. The level of significance used was the 95% confidence interval ($P<0.05$).

5.4 Results

Riding position

In walk the subjects were found to sit with a slight anterior hip deviation and an even lesser forward tilt of the upper body away from the vertical. Head and lower leg were considerably in front of the vertical.

When looking at the data a slightly smaller deviation of the head away from the vertical can be found in trot compared to walk with the trunk being slightly further behind the vertical. Lower leg deviation in trot was comparable to the same angle in walk. Relative angles were also found to be much the same as in walk; however, mean hip deviation reduced from nearly 7º down to 3.5º. No significant differences were found by a One-Way ANOVA. The general disposition of the rider displaying mean position on the horse was a slightly anterior hip deviation and head and lower leg in front of the vertical.

In canter significant differences were found by a One-Way ANOVA with Bonferroni Post-hoc test for trunk deviation ($F=13.72$; $df=2$; $P<0.001$) and lower leg deviation ($F=8.179$; $df=2$; $P<0.001$) between canter and walk and trot, relative neck angle ($F=9.125$; $df=2$; $P<0.001$) between canter and walk and relative knee angle ($F=3.412$; $df=2$; $P<0.05$) and total deviation ($F=3.189$; $df=2$; $P<0.05$) between canter and trot. The lower leg deviated further from the vertical than in the other two gaits and the trunk deviation was greater as well, with the head deviation being similar to that in walk and trot. Total deviation is therefore also greater in canter. With the trunk further forward and the head deviation staying the same the relative neck angle was also increased. Relative trunk and knee angles were contracted in comparison to walk and trot. General picture of the mean riding position would be described as further away from the vertical with proximal and distal limbs contracted further towards each other.

The detailed descriptive statistics are specified in Table 5.1 and an illustration of the riding positions, as well as an example picture of a rider demonstrating the approximate angles on the mechanical horse are found in Figures 5.2 to 5.4 and Plates 5.1 to 5.3.

Table 5.1: Descriptive Statistics of all angles in walk, trot and canter.

		N	Minimum	Maximum	Mean	Std. Deviation
Head deviation	Walk	36	2.56	24.73	12.68	5.35
	Trot	37	.45	21.29	10.84	4.90
	Canter	37	-8.90	22,45	10.76	5.74
Trunk deviation	Walk	34	-9.79	6.81	0.57	3.37
	Trot	33	-15.46	7.03	-.08	4.30
	Canter	35	-2.64	10.64	4.08	2.83
Lower Leg deviation	Walk	38	-0.33	12.68	5.16	3.16
	Trot	38	.25	12.74	5.83	3.02
	Canter	36	-.97	16.48	8.15	3.76
Relative Neck angle	Walk	38	152.95	178.27	166.35	6.72
	Trot	38	156.34	200.46	169.65	8.06
	Canter	38	161.93	192.24	173.44	6.86
Relative Trunk angle	Walk	38	152.01	194.61	170.57	12.77
	Trot	38	149.89	194.46	172.46	13.79
	Canter	38	140.05	204.88	167.65	16.98
Relative Knee angle	Walk	38	124.49	152.93	139.33	7.75
	Trot	38	129.22	155.24	140.01	7.41
	Canter	38	123.46	153.75	135.60	8.57
Total deviation	Walk	32	5.73	32.52	20.65	6.82
	Trot	32	7.75	31.88	19.25	6.59
	Canter	32	13.61	37.70	23.26	5.93
Hip deviation	Walk	19	-4.79	15.78	6.57	4.63
	Trot	20	-7.76	10.37	3.50	4.65
	Canter	21	-5.49	11.18	3.76	4.53

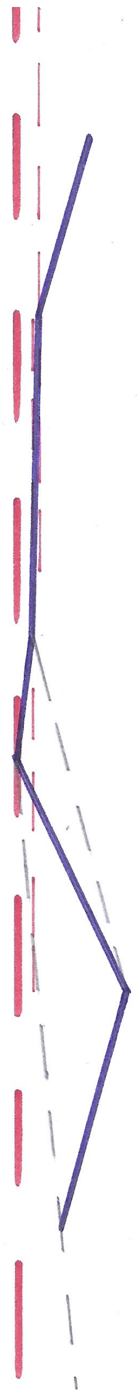

Figure 5.2: Illustration of the mean angles in walk.

Plate 5.1: Photograph of a rider demonstrating the mean angles of walk on the mechanical horse.

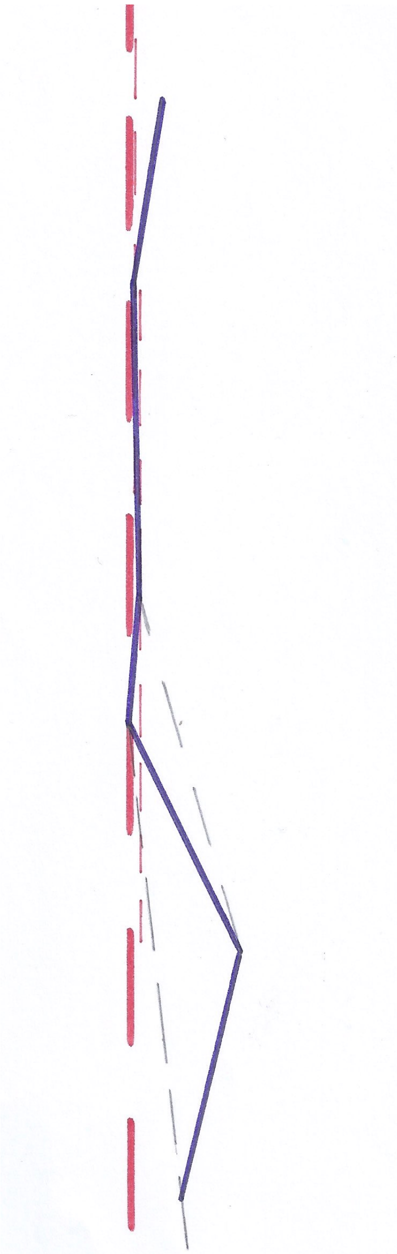

Figure 5.3: Illustration of the mean angles in trot.

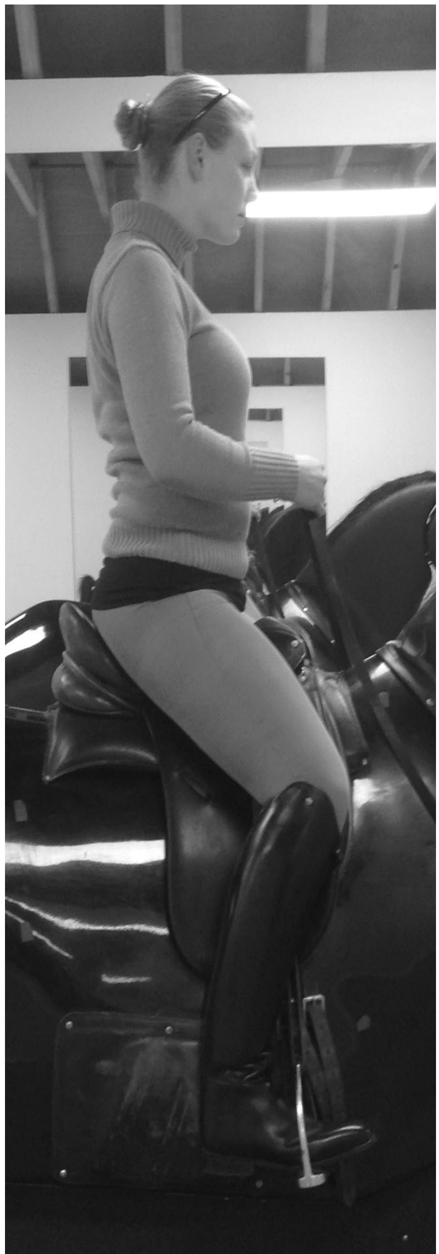

Plate 5.2: Photograph of a rider demonstrating the mean angles of trot on the mechanical horse.

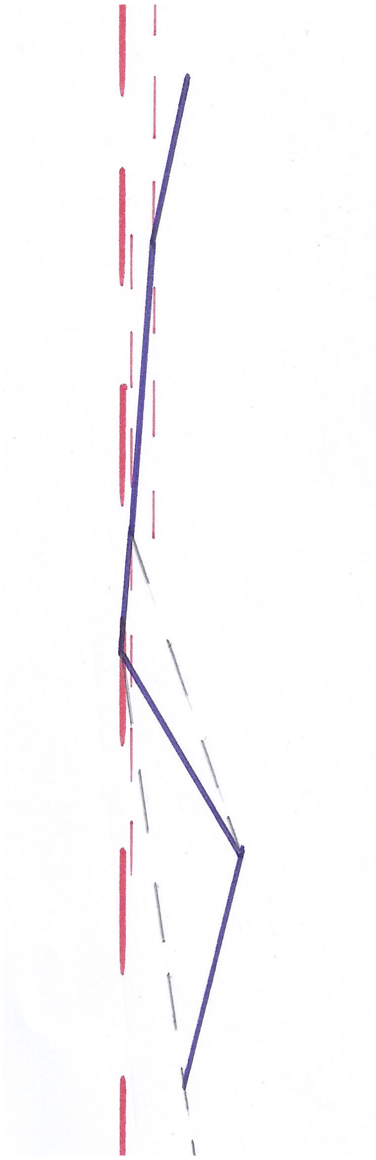

Figure 5.4: Illustration of the mean angles in canter.

Plate 5.3: Photograph of a rider demonstrating the mean angles of canter on the mechanical horse.

TekScan Pressure Analysis

The peak pressures that were recorded ranged from a minimum of 46.2 KPa to a maximum of 234.8 KPa. Generally pressure increased from walk to trot, but decreased again in canter; however, no significant differences were found using the One-Way ANOVA. The mean also shows that riders tend to sit further forward in walk and trot and more posterior in canter with higher peak pressures on the left side of the mat than the right. Minimum, maximum and mean with standard deviations are shown in Table 5.2 below.

Table 5.2: Descriptives of the Tekscan peak pressure Data for all gaits.

	N	Minimum	Maximum	Mean	Std. Deviation
Walk					
Anterior (in KPa)	14	63.00	219.40	142.46	38.22
Posterior (in KPa)	14	46.20	231.30	130.37	44.15
Left side (in KPa)	14	52.40	230.60	140.17	43.56
Right side (in KPa)	14	56.80	220.10	132.65	40.54
Trot					
Anterior (in KPa)	14	98.80	225.50	166.03	31.56
Posterior (in KPa)	14	126.60	211.70	158.59	26.32
Left side (in KPa)	14	126.60	234.80	164.81	31.04
Right side (in KPa)	14	125.80	202.40	161.51	23.66
Canter					
Anterior (in KPa)	14	121.30	210.20	150.76	24.61
Posterior (in KPa)	14	124.90	223.00	157.39	27.96
Left side (in KPa)	14	123.40	231.30	158.69	28.84
Right side (in KPa)	14	113.90	201.90	149.46	24.71

Anterior and posterior peak pressures were found to be significantly different in walk ($t=4.554$; $df=13$; $P<0.001$) and canter ($t=-2.801$; $df=13$; $P<0.05$) as well as between the left and right in canter ($t=2.520$; $df=13$; $P<0.05$).

Riding position

To establish whether there was a relationship between the peak pressures exerted onto the mat by the rider via the saddle, riding position data was correlated with the peak pressure readings. No correlation between pressure under the saddle exerted by the rider were found in walk and in trot. In canter all pressure readings have been found to correlate with the deviation of the trunk away from the vertical (Table 5.3).

Table 5.3: Correlations between trunk deviation in canter and Tekscan pressure data.

	Anterior pressure canter (in KPa)	Posterior pressure canter (in KPa)	Pressure left canter (in KPa)	Pressure right canter (in KPa)
Pearson Correlation	.822	.822	.878	.727
Sig. (2-tailed)	.001	.001	.000	.005
N	13	13	13	13

Questionnaire

One-Way ANOVA with Bonferroni Post-hoc test was used to investigate the relationships between riding position and riding experience as well as riding frequency. Experience was measures in the amount of years the subjects have been riding and for this the analysis was grouped into three groups (less than 10 years, 10-20 years, 20 years or more). Detailed statistics are shown in table 5.4 below.

Table 5.4: One-Way ANOVA between riding position and riding experience with the greek letters indicating significant differences as indicated by the Bonferroni post-hoc test (P<0.05).

	F	**Sig.**	n=15	n=13	n=8
Riding experience			**<10 years**	**10-20 years**	**>20 years**
Walk					
Trunk deviation	5.365	0.010	-.47 ± 3.56$^{\alpha}$	-.23 ± 2.68$^{\alpha}$	3.60 ± 2.22
Relative trunk angle	8.989	0.001	165.7 5± 11.34$^{\alpha}$	168.02 ± 11.10$^{\alpha}$	184.65 ± 8.12
Trot					
Relative trunk angle	6.026	0.006	168.10 ± 11.94$^{\alpha}$	169.87 ± 14.69$^{\alpha}$	185.71 ± 6.46
Canter					
Relative trunk angle	4.677	0.016	161 ± 16.01$^{\alpha}$	166.46 ± 18.35	181.94 ± 5.29

α= significant difference compared to >20 years

Having established that there were differences in riding position between those that have been riding for longer and those that are newer to the sport, it was of interest to establish whether these differences would have an impact on the pressure distribution. No significant differences between groups were found. An independent samples t-test, however, found differences that were significant and nearing significance between the pressure readings in trot and canter showing lower peak pressure readings for those riders that rode more hours per week (Table 5.5).

Table 5.5: Independent samples t-test between those who ride more and less frequently.

		t	**Sig (2-tailed)**	**df**
Trot	Anterior	2.620	.022	12
Anterior (in KPa)	Posterior	2.171	.051	12
Posterior (in KPa)	Left	2.461	.030	12
Left side (in KPa)	Right	2.348	.037	12
Right side (in KPa)				
Canter	Anterior	2.078	.060	12
Anterior (in KPa)	Posterior	2.369	.035	12
Posterior (in KPa)	Left	2.141	.054	12
Left side (in KPa)	Right	2.209	.047	12

Fitness parameters

Heart rate (bpm) ranged from a minimum of 125 to a maximum of 170 bpm with a mean of 146.12 ± 12.01 bpm on the exercise bike. On the mechanical horse the mean was lower with a greater standard deviation at 123.20 ± 26.37 and also a greater range from 85 to 173 bpm. A paired samples t-test showed a highly significant difference between heart rates ($t=3.276$; $df=11$; $P<0.01$). The mean VO^2max was 38.97 ml/kg/min ± 8.52 ml/kg/min with a range of 21.07 – 59.02 ml/kg/min (n=14). Gas analysis on the horse would be best carried out via a portable gas analyser, which was not available for this study as Writtle College does not own one, the $V0_2max$ was only reported on the cycle ergometer.

Overall core strength measurements ranged from 86 seconds to 362 seconds with a mean of 234.39 ± 78.20 seconds. Subjects mean durations were very similar with 38.94 ± 24.02 seconds on the left and 38.00 ± 20.64 seconds on the right, though they seemed to generally be stronger in their left side with a range of 12 to 150 seconds in comparison to 9 to 90 seconds on the right side, but no significant difference was found.

Mean balance scores were higher on the right side at 17.69 ± 17.02 seconds ranging from 2 to 52 seconds, than on the left at 16.44 ± 13.36 seconds ranging from 2 to 80 seconds, though no significant difference was reported. Total balance was recorded between 5 and 132 seconds with a mean of 34.14 seconds.

Total flexibility scores were recorded between 66 and 111 with a mean of 83.85 ± 9.86. Taking only into account those flexibility tests that test for hip flexibility the mean was 14.06 ± 6.08 with a range from 6 to 25.

Heart rates did not correlate with any other fitness parameter. Core strength readings for both the left (R=-.386; n=36; P<0.05) and the right (R=-.375; n=36; P<0.05) side correlated significantly with hip flexibility. Overall core strength recordings on the other side were found to correlate with the right balance times (R=.345; n=36; P<0.05).

Significant difference between groups was found only in those with better and poorer hip flexibility scores and the left and right core strength times. The mean core strength times in those with poorer hip flexibility were 48.21 ± 28.36 and 46.37 ± 22.01 for right and left respectively and the mean times for those with the better hip flexibility were 28.59 ± 11.86 and 28.65 ± 14.51 (Figure 5.5). A One-Way ANOVA also showed significant differences in flexibility and hip flexibility between those who have more and less riding experience (Table 5.6).

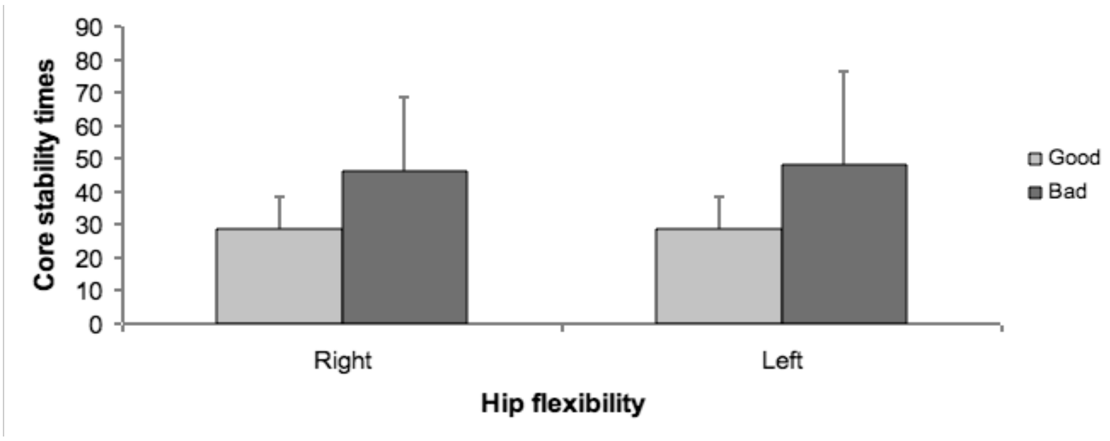

Figure 5.5: Significant differences between good (n=18) and poor (n=18) hip flexibility scores and right and left core strength times.

Table 5.6: One-Way ANOVA between flexibility scores and riding experience with the greek letters indicating significant differences as indicated by the Bonferroni post-hoc test (P<0.05).

	F	Sig.			
Riding experience			**<10 years (n=14)**	**10-20 years (n=15)**	**>20 years (n=7)**
Flexibility	5.426	0.009	86.25 ± 7.58$^{\alpha}$	86.20 ± 10.27$^{\beta}$	74.00 ± 7.52$^{\alpha\beta}$
Hip flexibility	3.920	0.030	15.21 ± 6.90	15.47 ± 5.28$^{\alpha}$	8.71 ± 2.50$^{\alpha}$

Fitness and riding position

To investigate what relationship exists between riding position and these fitness parameters independent t-tests and Pearsons bivariate correlations were applied.

Heart rate and core strength showed no correlation with riding position. Hip flexibility was linked to the seat having very highly significant negative correlations with relative trunk angles in all gaits and relative knee angles in trot and canter with walk being highly significant. Other angles that were negatively significant were trunk deviation in walk and trot and lower leg deviation in canter. Overall balance was negatively correlated with the head deviation in canter. The detailed test statistics are shown in Table 5.7 below.

Table 5.7: Correlations between fitness parameters and riding position angles.

		Pearson Correlation	Sig (2-tailed)	N
Hip Flexibility	Trunk deviation walk	-.494	0.004	32
	Relative trunk angle walk	-.700	<0.001	36
	Relative knee angle walk	-.501	0.002	36
	Trunk deviation trot	-.608	<0.001	32
	Relative trunk angle trot	-.746	<0.001	36
	Relative knee angle trot	-.580	<0.001	36
	Lower leg deviation canter	-.373	0.030	34
	Relative trunk angle canter	-.729	<0.001	36
	Relative knee angle canter	-.578	<0.001	36
Balance Total	Relative trunk angle canter	-.355	0.043	33

HR did not correlate with any riding position angles; however, predicted VO^2max showed significant correlation with the total deviation in trot (R^2=.688; n=11; $P<0.05$) and the lower leg deviation in canter (R^2=.743; n=14; $P<0.01$).

When comparing riding position between those with good (combined duration >30secs) and poor (combined duration <30secs) standing balance significant differences were found in the relative trunk angle. On average the trunk angle in those with better standing balance was just under 9° smaller than that of those with poorer balance.

Hip flexibility groups (divided by mean) showed significant difference for the trunk deviation in walk and trot, the lower leg deviation in walk and canter and relative trunk angles in all three gaits. Significant difference was also found for total deviation in canter. Mean angles and standard deviation as well as statistical results are shown in Table 5.8.

Table 5.8: Difference between hip flexibility groups on riding position (Mean angles and standard deviations in º).

	Poor (n=19)	Good (n=17)	t	df	Sig. (2-tailed)
Balance					
R. trunk angle canter	173.89 ± 16.49	162.96 ± 15.60	2.035	34	0.050
Hip Flexibility					
Trunk deviation walk	2.42 ± 2.47	-1.23 ± 3.43	3.454	30	0.002
Lower leg deviation walk	6.08 ± 3.01	3.83 ± 2.87	2.284	34	0.029
R. trunk angle walk	179.91 ± 9.16	162.13 ± 8.21	6.105	34	0.000
Trunk deviation trot	2.25 ± 1.81	-3.35 ± 4.89	4.581	30	<0.001
R. trunk angle trot	181.94 ± 7.13	163.58 ± 12.81	5.389	34	<0.001
Lower leg deviation canter	9.72 ± 3.97	6.43 ± 3.03	2.719	32	0.010
R. trunk angle canter	179.24 ± 6.36	156.99 ± 17.12	5.279	34	<0.001
Total deviation canter	25.52 ± 6.76	20.94 ± 4.49	2.187	28	0.037

5.5 Discussion

The aims of this study were to understand the rider's seat in walk, trot and canter as well as the differences between the gaits. The angular characteristics and pressure distribution of the seat of the more experienced riders against those with less experience were also compared. The general fitness of a cross section of the horse riding community was then established and the effect of balance, flexibility, core stability and cardiovascular fitness on rider position investigated. The research findings were laid out in the results section above and will now be discussed and brought into relation to existing research on fitness in equestrian athletes and the effect on performance.

Riding position

When looking at the angles in walk it was found that the head and lower leg deviated anteriorly from the vertical with only a very slight leaning forward of the trunk (Table 5.1). Having previously established that the balanced seat would be a straight vertical line through ear, shoulder, hip and heel the mean total deviation from this position in walk was found to be 20.65° ± 6.82° (Deutsche Reiterliche Vereinigung, 1996). The head and lower leg deviations are likely to be linked because when the head is flexed forward the rider offsets his balance and therefore needs to compensate to regain stability by positioning his legs anteriorly as well. It is unclear which is the cause and which the result as this information lays outside of what this study investigated. The hip deviation which shows the positioning of the lateral iliac crest in relation to the greater trochanter was found to be at 6.57° ± 4.63° anteriorly. The head and lower leg come forward in front of the vertical so it could be hypothesised, that the rider’s body becomes more flexed forwards.

Because the trunk and knee angles increase along with the head and lower leg deviations the rider is expected to lean their trunk forwards with their head extended even further anterior while pushing their feet forward to maintain balance.

The balancing mechanism can be compared with that of squatting on the ground. The further the knees are flexed, the further the centre of gravity moved behind the buttocks and the further forward the subject must lean to remain balanced (Schoenfeld, 2010). This is also in line with riding theory, where even Xenophon has already stated that riding should be less like sitting on a chair, but more like standing with the legs slightly flexed and slightly abducted (Widdra, 2007).

The position of the rider in trot and canter were similar with the following notable differences. Head deviation as well as hip deviation were found to be smaller in both trot and canter (Table 5.1). Trunk and lower leg deviations were significantly different between walk and canter as well as trot and canter with canter having the largest deviations. The relative neck angle increased from walk through to canter with a significant difference between walk and canter. The relative trunk angle was smallest in canter with a significant difference between trot and canter. Total deviation was largest in canter with trot and canter also being significantly different and hip deviation was largest in walk. It seems that canter was most unlike the other two gaits, which could be due to the nature of the gait with its increased forces acting upon the riders (Back and Clayton, 2001).

This study was carried out on a mechanical horse, which simulates, but not identically applies the forces onto the rider with the breaking and propulsion (longitudinal GRF) being much lower due to the mechanical horse being stationary. Despite the change in forces acting upon the rider a pilot study carried out showed no significant differences between riding position on the mechanical horse as opposed to the real horse. These findings are in accordance with an unpublished previous study by Marloes Vogel (personal communication) investigating the differences in riding position between the mechanical and real horses.

TekScan

Pressure data would confirm the leaning forward theory with higher mean peak pressure being recorded in the anterior half of the mat (Table 5.2). The lower leg deviation increases which means that the foot would have to be pushed forward and the knee downwards effectively increasing the knee angle and extending the leg. This scenario is described in the common riding fault called the “chair seat” (Auty, 2006). In this position the rider shows a slight posterior tilt of the pelvis. The biomechanical back model by Hess *et al.* (2012) would further support this theory with the statement that a more anterior tilted pelvis leads to a more upright back with the shoulders rotated posterior.

No professional rider took part in this study with all subjects being relatively novice amateurs. To assess the actual skill level of each rider would have been outside the scope of this study as this a complex task in itself. Assuming that the majority of riders had a skill level of no more than elementary dressage, this study further supports the findings of Muenz *et al.* (2014) who found professional riders to have a more posterior tilted pelvis as opposed to the leaning forward of beginners. The same differences in riding position were also recorded by Schils (1993), Lovett *et al.* (2004) and Kang *et al.* (2010). To know for certain that the results agreed with those of previous studies, it would have been necessary to document the actual riding skill of each rider at the time of recording, though this is in itself is a difficult task as it cannot be objectively measured. The correlations between the trunk deviation in canter and all pressure readings (Table 5.3) shows a direct effect of the anterior tilt of the trunk and increased pressure asserted onto the saddle. Considering that the anteriorly tilted trunk was found to be a sign of a novice rider, higher pressure could also be assumed to be a trait of the less skilled rider.

Mean peak pressure data shows that in walk and trot more pressure is distributed onto the anterior half of the saddle mat, whereas in canter the higher mean pressure is recorded in the posterior half of the mat (Table 5.2). In all gaits the higher mean peak pressure was recorded on the left side, though this was only significant in canter. This supports previous studies suggesting that medio-lateral asymmetry in the rider is a common problem, which has been recorded in the shoulder (Symes and Ellis, 2009), the reins (Warren-Smith *et al.*, 2007) as well as the pelvis (Nevison and Timmis, 2013; Muenz *et al.*, 2014). Clayton (2013) suggested the reason for this being a stronger flexion in the hip of the dominant side. Nevison and Timmis (2013) found a higher pressure distribution in square centimetre on the right side in 5 out of 6 subjects pre intervention, which seems to be on the contrary to this present study, though pressure area (in cm^2) and peak pressure (in KPa) are not directly comparable, so it could have been worth looking at the pressure area as well to acquire comparable results. In their paper Nevison and Timmis (2013) stated that they had also looked at peak pressure (in KPa) as well as mean pressure (KPa), maximum force (N), excursion of the centre of pressure (mm) and contact area (m^2), but recorded no significant differences between left and right measures and did not state whether there was a difference in the means. Muenz *et al.* (2014) recorded a tendency of beginner riders to tilt their pelvis to the right. He also found elevation of the right ischium and posterior ilium caused by the anteroventral tilt of the right ilium. They suggest that rather than causing a lift of the right side of the pelvis this could lead to the right hip flexors pulling the right side of the hip down. The study at hand would not support their theory, but suggest that the right side of the pelvis was lifted slightly, causing the left peak pressure readings to be higher.

Significant differences were found in pressure reading between those who ride more than five hours and those who rode less than five hours per week in trot and canter (Table 5.5). The data suggests that those who ride more frequently not only have a lighter seat, but also a more balanced one with more equal pressure readings between anterior and posterior as well as left and right sensors particularly in trot, but also in canter. This could be explained by the fact that those who ride more often are more practiced and are more able to relax in the saddle and therefore reduce the tension that would make for increased peak pressures. To investigate this matter further it would be interesting to compare pressure readings between novices and more advanced riders, which could also explain the correlation between higher pressure in those who show a larger anterior tilt of the trunk as mentioned earlier.

Riding experience

When comparing riding position between experience groups significant differences were found between the groups (Table 5.4). The more experienced showed a greater relative trunk angle in all three gaits and a greater trunk deviation in walk. Because the relative trunk angle was found to be correlated to greater lower leg and hip deviations as well as greater relative knee angles the results suggest that decreased flexibility could be the cause for the less ideal seat in those who have been riding for more than 20 years, because they are also likely to be of older age. This hypothesis is further supported by the significant difference in flexibility as well as hip flexibility scores between the riding experience groups with those riding more than 20 years having significantly lower scores than those who have been riding less than 20 years.

Fitness parameters

Aerobic capacity findings were similar to those of previous studies, though slightly lower than those of Westerling (1983), who also used a cycle ergometer, but induced maximal effort, but higher than Meyers and Stirling (2000) who used a treadmill for maximal testing. The results of this are contrary to other authors that reported bicycle ergometer tests to underpredict maximal aerobic capacity (Mazzeo and Marshall, 1989; Withers *et al.*, 1981). Interesting is also that Westerling (1983) found no difference in static muscle strength in riders as compared to non-riders. He also found that aerobic capacity of horse riders was superior to other comparable groups. Because Alfredson *et al.* (1998) reported high thigh strength in riders there is possibility that leg muscle endurance might be higher in equestrian athletes, causing these results, though this would be subject to further investigation. No significant findings were recorded for aerobic capacity and walk, as opposed to some significant in riding position angles in trot and canter. This is expected to be related to the increased aerobic cost of these gaits (Westerling, 1983; Devienne and Guzennec, 2000).

The total deviation in trot was found to be greater in those with a higher aerobic capacity. In canter lower leg deviation was found to correlate significantly with the predicted VO^2max. These results would suggest that those with a greater aerobic capacity sit further away from the vertical as total deviation increased in line with the predicted VO^2max in trot. For canter it was previously discussed that a greater relative trunk angle resulted in greater lower leg deviation, hip deviation and relative knee angle resulting in what was described as the “chair seat” which was a forward flexing of both the upper body and the lower limbs. Because the mean predicted VO^2max was found to be in a normal range and there being no correlation between heart rate on the horse as opposed to the mechanical horse it could be concluded that aerobic capacity is of marginal importance to the seat of the rider. This would have to be further explored, though, as this study only required the riders to sit on the mechanical horse and be recorded for a very short amount of time and there was no means of telling whether aerobic capacity would have an impact on position if the subjects would have asked to ride for prolonged periods of time and fatigue would have set in.

It has been found that the group of riders that were classed to have better balance had lower relative trunk angles in canter (Table 5.7). If the balance was transferred from standing to seated on the horse, and therefore a seat close to the vertical was assumed it could be hypothesized that those with better balance were riding with shorter stirrups and thus greater flexion in their knees.

Hip flexibility seemed to have the highest impact on riding position showing the most significant differences in riding position between those with better and lower flexibility scores (Table 5.7). Trunk deviation in walk and trot was found to be lower in those with good hip flexibility who showed mean angles that were found slightly behind the vertical, which could suggest that those with better hip flexibility find it easier to tilt their pelvis slightly more forward and sit with a more upright back and posteriorly rotated shoulders as has been identified as ideal riding position (Hess *et al.*, 2012). Lower leg deviation as well as total deviation were also significantly smaller in those with good hip flexibility in walk and in canter. The relative trunk and knee angles in all three gaits were found to be smaller in those with good hip flexibility.

Looking at these results it could be said that those with better hip flexibility would show a seat that is closer to the vertical, but also with smaller relative trunk and knee angles. This would suggest that the riders were riding with shorter stirrups and thus greater flexion of the trunk and knees, which could have caused them to be more stable and therefore be able to sustain their position straighter. To know this for sure further investigation would be necessary also recording stirrup and/or leg length. A significant difference between hip flexibility groups was also recorded with those with better hip flexibility having the significantly lower core strength times (left and right), so it could be possible that those with lower core strength times chose to ride with shorter stirrups and therefore the results for balance in this study could be biased.

Another possibility would be that those with the weaker core strength measures had less tension and were therefore more flexible through their hips. It is likely that they would have had a higher range of motion during the stride; however, so it would be interesting to investigate this further. Riding theory makes clear that a common misunderstanding of aligning the heel with the hip is to simply pivot the lower leg at the knee and move the foot posteriorly to bring it underneath the hip; however, the aligned leg starts from the pelvis and requires a stable, balanced seat (Dietze, 2003).

The subjects of this study were amateur riders, so it would also be interesting to see what the average fitness parameters are in professional dressage riders and how their fitness relates to their seat. Probin (2014) found that at Grand Prix level, older, more experienced riders show less muscle activity using an EMG whilst performing advanced movements than their younger counterparts, which underlines Terada *et al.*'s (2004) findings that muscle activity (also measured via EMG) for riding should predominantly be used for posture and co-ordination. Posture can be described as continuous balancing of the body parts and can thus be classed as a dynamic activity that requires a minimum of movement and tension to retain balance. Balance has also been found to improve with core stability training (REF). With this in mind all faults in riding could theoretically be considered balance issues that affect the harmony of the rider and the horse. Some more minor issues can be corrected through muscle contractions, but this leads to tension. Generally all loss of balance can only be compensated for with increased force or counter movement. For example when getting on a balance beam the automatic reaction when balance is offset would be to compensate by using the arms to counterbalance by lowering the centre of gravity. This study showed a significant difference between those with better and worse balancing scores and their relative trunk angles in canter. Those with better balance scores showed smaller relative trunk angles. Overall balance and the relative trunk angle in canter also showed a significant negative correlation. Taking into account that the relative trunk angle was also associated with a more upright position and smaller lower leg deviation it can be said that better balance would lead to a more upright position closer to the vertical. Right balance also correlated negatively with the trunk deviation and the relative knee angle in canter. The same tendencies were found for left and total balance, however were not significant. It seems that in canter those that have better balancing times seem to lean back with their trunk, using their head and lower legs as counter weights as not to lose their balance.

It has been noted that the frequency of back pain in horse riders (Quinn and Bird; 1996) and their horses (Dyson, 2000; Nadeau; 2006) is quite high and this could be due to the asymmetry seen in the pressure data. The muscle recruitment strategies used by the nervous system to cope with back pain may become less efficient and lead to further deterioration of musculoskeletal health in rider, which in turn could cause injury in the horse. Nevison and Timmis' (2013) intervention showed reduced bilateral asymmetry in pressure distribution and increased postural stability on a static saddle horse through physiotherapy. It would be worth investigating the effects of physiotherapy and core stability training techniques on the pressure distribution in a dynamic setting, such as the mechanical horse, or in a more real life setting on an actual horse.

5.6 Conclusion

In conclusion the results of this study were mostly in line with other research on the subject showing that the relative novice rider displays a forward tilt of the trunk and to maintain balance also flexing forward of head and lower leg. It should be noted that the riding experience in years may not be compared with riding skill as those with more experience showed a less ideal seat, which was explained by decreased flexibility and could therefore be due to ageing. Aerobic capacity seems to not have made major impact on riding position though higher deviations from the vertical were recorded with increased cardiovascular fitness. It can, however, be assumed that as long as a basic level of aerobic capacity is established the effect on riding position is marginal. This is true for simple riding position and other forms of equestrianism may well be more impacted by it. Hip flexibility seemed to have the biggest impact on riding position allowing for a more anterior tilt of the pelvis and thus decreasing all other deviations from the vertical. Position seems to be shortened at the same time, which could be due to stirrup length, but this is to be investigated further. Increased hip flexibility was also associated with decreased core stability. Whether core strength is detrimental to a more upright seat could be arguable. Increased balance was also suggested to lead to a straighter position. Imbalances in pressure distribution between left and right as well as front and back contribute to the understanding that medio-lateral imbalances in the horse rider are common and solutions need to be found for the welfare of both horse and rider. More riding practice was also found to decrease and balance pressure exerted onto the horse's back. Intervention studies seeking to improve rider asymmetry are highly recommended.