How should golfers monitor training load?

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Abstract

Training load monitoring has been integrated into a variety of sports at a high level over the past decade. However, it has been presented by various authors that golfer's sustain injury caused by overuse of specific sites of the body. This is done without knowledge of golf specific training loads and little academic research into training load monitoring within golf. Therefore, it is reasonable to suggest that the topic of load monitoring in golf should be researched, as load monitoring in other sports has been researched. Such studies have lead to the quantification of load and acute chronic workload ratios by academics.

Two literature reviews; one on injury in golf and one investigating training load monitoring in other sports preceded a set of semi structured interviews with subjects working as coaches, doctors, physiotherapists and players within international golf. The purpose of the semi structured interviews was to discuss topics relating to golfing load, summarise the opinions of the experts on those topics and define the importance of each topic relating to a golf specific load monitoring tool.

Acknowledgements

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A final mention goes to those closest to me from the start, my family. It is their love, commitment and encouragement that got me through some testing times here and they are a significant factor in this piece of work is now being complete.

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Glossary of Terms

ACWR	Acute : Chronic Workload Ratio
CHS	Clubhead Speed
Km/h	Kilometres Per Hour
LM	Load Monitoring
PRISMA	Preferred Reporting Items for Systematic Review and Meta Analysis
RFP	Rate of Force Production
RPE	Rate of Perceived Exertion
TRIMP	Training Impulse
TSB	Training Stress Balance

Chapter 1

Introduction

1.1 Motivation

The motivation to undertake this research piece came from a variety of factors. By studying a master's degree, additional career development pathways as a sports therapist will open up and the transferable skills of further study will be applicable to my profession following the completion of this degree.

Furthermore, it is apparent at the beginning of this research piece that workload across all sport is important and the application of research practice in sport provided a strong motivation to contribute a piece of work to be taken forward. Clearly there is a gap between the practice of load monitoring in golf and prior research to inform practitioners of the scientific evidence behind load monitoring.

Additionally, golfer's sustain injury across practice and competition with many high-level golfers not monitoring their workloads. Many professionals working within golf, particularly at a high level rely on their own experiences and that of their peers thus developing a practice-based evidence approach to the topic of load monitoring. As a final note, this research piece aims to provide a start point for future researchers and to investigate the potential inclusion topics for a golf specific load monitoring tool for future development and refinement.

1.2 General Introduction

Golf is one of the most popular sports worldwide with 29 million players in the United States and an estimated 55-80 million worldwide. (1,2) Furthermore, the game is developing with greater prize money, lucrative sponsorship deals and highly soughtafter television rights. Professional golfers spend countless hours dedicating themselves to improvement on and off the course due to the constantly evolving demands of the sport. Courses are becoming longer, (3) and players are hitting the ball further now compared to the turn of the century. This could be in part due to increased physical attributes in conjunction with ever improving technological advancements of clubs and golf balls. Such improvements have led to an increase in distance hit and courses having lengthened in response to this. Coupled with this, the relative increased professionalism and time spent practicing puts an elite golfer at a higher risk of overuse injury. (4)

The physical characteristics of a high level golfer have been documented within the recent literature. (5–7) Sell *et al.* (5) observed that elite right handed players showed better balance on their right legs leading to the opinion that the golf swing requires greater balance on the downswing than the upswing. There was also significantly larger hip, torso and shoulder strength observed in high level golfers compared to less proficient participants. A none elite male golfer was identified as someone with a handicap of 10-20, with handicap being the numerical measure of a golfer’s ability, the lower the number the better the player. Golfers with greater strength have been shown to hit the ball further, (6) with these strength gains attributed to physical training, although increased training hours are an external factor for injury in an athletic population. (8) In addition to this, rate of force production (RFP) is also increased when strength improves so the forces applied to a golfer’s body may be higher the stronger a golfer becomes. With this in mind, the monitoring of golf load could be important, to account for injury risk within that individual.

It was noted by Hellstrom. (9) that the physical differences of high level (handicap of less than 10) and less proficient golfers may be due to different capacities of fitness and golf volumes. With physical characteristics such as height and limb length relating to clubhead speed and ball flight, Dorado *et al.* (10) stated that there is a correlation between physique and driving distance and that muscle power is an important characteristic to take into account regarding clubhead speed (CHS). Height and arm length were significantly correlated to swing speed, long arms coupled with a large usable muscle mass create high strength and power output. These factors, as well as an individual's flexibility are likely to impact a players technique and thus the ability to create CHS. (9) From this increase in CHS comes the additional distance which is key to golfing performance. The relationship between muscular strength in golfers and their proficiency has been researched with findings between muscle strength, swing performance and proficiency reported. (6,7) CHS has been identified as a key component of a category one golfer enabling greater ball distance with a higher club (greater angle of clubface) and therefore allowing for greater control as the ball path will have a higher arc but travel less distance. (11)

Golf, in particular at an elite level, requires a complex combination of skills and characteristic's physically, psychologically, technically and tactically for a performer to compete at their best. (9) To some extent, the physical requirements for high performing golfers and the prevalence of injury at an elite level have been investigated in previous literature. (9,12,13) There is a requirement for further research regarding injury mechanism for specific joints in the body, (14–16) relating to all categories of male and female golfers. With literature and research being dedicated to the statistics and possible causes of golfing injury, it is important researchers look at data collection pertaining to injury rates too. By tackling the issue of how to channel the previous literature into combatting injury rates, this will create a demand for investigative literature proving that preventative steps are working in reducing golfing injuries.

Golf has been shown to be a low intensity sport in younger adult populations given it typically requires less than 50% of a young adults maximum heart rate (MHR) to carry out the activity. (17) An 18-hole course can take between 3-6 hours to complete and whilst walking the course, players carry out low intensity aerobic exercise irrespective of skill level. However, the action of a club swing is short and dynamic, being performed in approximately one second for a full swing, with CHS reaching 160 km/h. (18) The biomechanical forces placed upon specific joints throughout a complete golf swing and follow through are immense, thoracic (torso) rotation in professional golfer's ranges from 78° to 109° and pelvic rotation has been observed at 37° to 64°. Changes in range of movement occur incredibly quickly to generate CHS and distance. Furthermore, through EMG research, the trunk extensors, hip extensors and abdominal muscles all play a pivotal role in producing a powerful efficient swing. (18,19) Of similar importance is the transfer of energy from lower to upper body muscle groups in the chest and shoulders as they contribute to the physical output leading to the production of high clubhead speed.

Given that golf swing occurs for a short duration it enables athletes to train everyday often exceeding 300 full swings daily. (20,21) The action of a golf swing creates high physical stress and exertion on the body. As such, it is imperative that golfers are robust enough and have had the exposure to a consistently appropriate load to reduce the risk of injury. The presence of desirable biomechanical traits such as the mobility and flexibility around a joint to create the requisite forces of an efficient and powerful swing are fundamental aspects of a golfer being successful. However, as Windt *et al.* (22) stated the ability of an athlete to sufficiently cope with a specific load injury free, enables more time to be spent practicing and that in itself could form a potential injury risk increase as there are a greater number of opportunities for injury to occur.

Injury in golf is common, (12,21) with up to an 88% annual prevalence of injury amongst professional golfers. An average of almost two injuries per player per year is associated with increased hours of play and therefore a greater risk of a golf specific injury occurring. (21) Throughout golf injury literature, studies found commonality with overuse injuries occurring more frequently than acute traumatic events. (4) An overuse injury is defined as a sustained repetitive trauma stemming from a combination of training and technique errors. Gosheger *et al.* (4) observed that back injuries were most common (18.3%) followed by the elbow (17.2%) and then ankle (12.9%). Marshall *et al. found* knee injury in golf to be less common but when injury does occur, it is often traumatic and can lead to extended periods of rehabilitation and practice time lost. (23)

Overuse injuries are the most common cause of injury in elite golfers with biomechanical and technical aspects potentially causal (24–26), there is little evidence to suggest that golfers, even at the elite level, monitor their workload on a day to day basis for any period of time. Given this, the relationship between training load (TL), illness and injury is less advanced within the realms of golf compared to other sports. (27) TL was initially defined by Bannister as the product of training volume. Bannister came up with the theory of a training Impulse (TRIMP) as a unit of measurement for training load. A TRIMP is a unit of physical effort that is calculated using training duration and maximal, resting, and average HR during the exercise session. (28) More recently, Gabbett *et al.* have defined load as ‘‘the cumulative amount of stress placed on an individual from multiple training sessions and games over a period of time, external workloads performed or the internal response to that workload.’’ (29)

Subsequently, there is now a demand to research golf and training load the degree that has occurred in other sports. With this, a greater understanding of sport specific training load monitoring may be reached. Recently there has been one paper published looking at the feasibility of the development of a golf specific load-monitoring tool by the Williams *et al.* (27) however prior to this, to the author’s knowledge there has been no research published within this area of literature.

Nonetheless, (27) provides a start point and a reference to future research on the topic. Given that overuse injuries through prolonged, frequent practice and competition schedules for an elite golfer are common, (13) the literature seems to indicate that research on the topic of workload management in elite golf needs to be addressed. This is due to the logical conclusions that can be drawn from the fact that currently golfer’s, even at an elite proficiency, do not appear to monitor their workload. Despite these findings, it is widely accepted that golfer’s frequently develop overuse injuries, (4,30) without correctly monitoring their training load. If correctly implemented, load monitoring may serve to decrease injury risk and reduce the amount of practice and playing time missed, as well as income opportunities from events.

With no quantifiable training load data available, a player may become more susceptible to an overuse injury, Pink *et al.* (31) found professional golfers to hit 2000 balls or more weekly as well as in excess of 200 balls daily when practicing, however these figures are slightly arbitrary regarding overuse injury owing to the fact that player’s appear to not track their own golf volume daily or over a greater duration. There have been recent and applicable examples of overuse injury at an elite level within golf and other sports too. World number one Rory McIlroy spent the winter of 2016 testing new clubs owing to his club provider withdrawing their production of clubs. An Increased acute workload where he hit “thousands of balls a week” assessing potential new club manufacturers may have caused a long-standing rib injury that plagued him for much of 2017.

1.3 Aims of the Research

This research aims to assess the current literature surrounding training load monitoring in various sports, (32–34) literature focusing on musculoskeletal injury in golf (12,16,35) and if some of the fundamental principles applied to load monitoring (LM) are transferable into the sport of golf. Furthermore, this research will assess and review the outcome of the past work and potentially establish inclusion topics for a golf load monitoring tool. Currently, there has been one identified research paper published surrounding golf specific training load monitoring, (27) with one aim of this piece of research to further add to the literature area and seek the expert opinion of a range of practitioners potentially utilised by a high level golfer throughout the course of their season.

1.4 Research Questions

In order to meet the purposes of this piece of research project, the following research questions were proposed.

Q1. What does the current literature indicate regarding the incidence and prevalence of musculoskeletal injuries at common injury sites in Golf?

There is a limited literature investigating the topic of injury in golf, however it is important to ascertain a breakdown of specific injury sites and the commonality of injury in golfers from the literature available. Expanding upon this, it may be of note if there is a difference in injury risk amongst high level golfer's that those who are less skilled may not be exposed to. Finally, the types of injury reported is of importance as well as the way in which such information is collected and reported by academic researchers.

Q2. *What is the current scope of literature exploring training load monitoring in other sports and can any current principles of load monitoring be applied to golf from other sports?*

Various sports have recently looked into training load volume from a scientific and quantifiable viewpoint. By investigating previous work, the researcher aims to identify an overall framework of total training load encompassing the entirety of an athletes workload and how each aspect is broken down. Finally, it will be looked at if any current load monitoring techniques from other sports may be identified as transferable into golf.

Q3. What are the components of a high-level golfer's training and which aspects of their training schedule should be included in a training load monitoring tool?

Elite golfers often have a multitude of resources at their disposal to help aid golfing performance. Players often are in contact with; coaches, strength and conditioning coaches, physiotherapists and or doctors throughout the course of a season. As such, these professionals will all have a unique viewpoint on the vital components of a golfer's day to day life that make up golfing 'load'. From this, a series of semi structured interviews will be compiled with the various professionals being represented and the primary topic of discussion being what they think is important to include within a golf load monitoring tool.

1.5 Outline of Literature Review one: Sites of injury in golf

Golf is considered a moderately low risk sport with regards to injury (0.9-1.4 per 1000 hours of participation), (36) however professional golfers experience on average 1.9 injuries a year. (12) This figure is higher than the number for amateur golfers, with a variety of factors being attributed to this, such as increased playing time, greater volume of practice and larger force exertion on the body. (9) This indicates that training load may be a driver for injury. Much of the research conducted on golfing injury have used a mixture of amateur and professional players (12,15,35) therefore a consensus on some injuries is difficult to establish. However, age and practice time are potential causes of many common golfing injuries. An increase in load does not necessarily guarantee and increase in Injury incidence, but as practice time and repetition increases, so too does the likelihood of injury with a greater amount of work carried out, particularly if training is not increased incrementally. (37) With regards to the areas of the body where injury occurs, lower limb injuries are found to be far less common and far less serious in nature than injury to the upper peripheral joints such as the shoulder and elbow. (4)

However, thoracic and lumbar spine injuries were found to have the greatest prevalence in amateur and professional golfers. The vast majority of injuries in golf stem from repetitive swing actions and overuse of a specific area of the body. (12) Overuse injuries are shown to represent a large proportion of professional and amateur injuries throughout golfing literature. (12,35) Amateur players often experience overuse injury due to poor preparation and warm up as well as swing technique deficiencies, whereas professional golfers experience overuse injury down to the volume of practice and play. (9,12,21) Much of the literature on golf injury is descriptive in its nature and injury pathology is not always present in written literature hence the internal validity and external validity of the findings may be affected by this. Internal validity is defined as the extent to which the observed results represent the truth in the population being studied. External validity is how well the results can be applied to a population outside of the current study. (38)

1.6 Outline of Literature Review two: Training Load Monitoring in other sports

Training load monitoring has, to a greater extent been researched across a selected range of sports including rugby, cricket and Australian Football League (AFL) football (22,39,40) with the primary objective of assessing injury risk and with the outcome goals of reducing injury risk and illness. (41) Absolute and relative loads are often used to calculate the 'acute: chronic workload ratio' (ACWR). This ratio takes the workload score from the previous 7 days and compares it to the previous month with a ratio of 0.8:1- 1.3:1 seen as the window of optimum workload with lower injury risk. (8) This however, is not a 'golden ratio' and the ACWR varies from amongst individuals. It has been found that high training loads can have a beneficial effect on an athlete regarding injury risk with the rate of load application combining with an athlete's internal risk factors being key to the outcome of the load. (8) Load should always individualised, not as a broad 'one size fits all' application if an athlete is part of a team . The individual's load should be flexible and adjustable within a training block. Furthermore, athlete's respond much better to minimal but regimented increases (or decreases) in load rather than fluctuating load. Much of the research states the importance of accurate quantification of external loads such as distance travelled or balls bowled to give an accurate total load which can then be applied to the clinical theories and hypotheses. Finally, it is acknowledged that more research is required regarding competition schedule and load changes across a broader variety of individual sports. (41)

1.7 Outline of study findings: How should golfers monitor training load?

Eight subjects participated in a semi structured interview answering questions and giving opinions in various topics related to golfing load. These topics included how to measure golf volume, including club grouping and measures of work done, measuring strength and conditioning work done, sleep and a section of a tool relating to injury. They were then offered the chance to give input on anything else they deemed relevant to the topic of golf specific training. Golfing load in this context refers to any aspects of work undertaken relating to golf performance, such as sport specific training and physical training. At the end of each interview the subjects were asked to rank the importance of each sub section on which they thought was the most important for inclusion within a golf load monitoring tool. The results highlighted that golf specific tasks were the most important inclusion topic for a load monitoring tool and that number of balls hit may be the best way to quantify this. Clubs should be categorised into three specific segments; drivers/woods, high irons, low irons owing to the different physical demands of such shots.

Regarding putting volume, it could be prudent to monitor the number of strokes made and the time spent practicing putting to obtain a putts per minute score. With their gym training sessions most participants said a simple RPE x time score would be an acceptable method but alternative offering of total tonnage calculated by load x reps for a session may also be helpful. Wellness was reported to be the third most important topic followed by injury and environmental factors. In conclusion, each expert had a slightly different take on golfing load from their personal perspective but a general consensus on the important topics to be included moving forward was reached.

Chapter 2

Table 1. Terms and definitions relating to Injury

Term	**Definition**
Acute Injury	*A single identifiable event that brings about a sudden trauma to a specific region of the body. (42)*
Overuse injury	*Sustained and repeated trauma over a period of time leading to damage. (4)*
De-Quervian's tenosynovitis	*An overuse disease that involves the thickening of the extensor retinaculum of the first dorsal compartment of the wrist. (43)*
Femoral Acetabular Impingement (FAI)	*An often painful pathological condition leading to surface interaction between the proximal head of the femur and acetabular rim. (44)*

Literature Review on the sites of injury in golf

2.1 Methods

2.1.1 Identification of studies

A review of previous work was completed in line with the Preferred Reporting Items of Systematic Reviews and Meta-Analysis (PRISMA) guidelines. A search of studies from PubMed, SPORTDiscus and Google scholar was carried out. The searched terms within the engines were a combination of: 'golf', 'golfer', 'injury' combined with 'cervical', 'lumbar', 'thoracic', 'ankle', 'knee', 'shoulder', 'wrist', 'hip'. A four-stage process was then used to complete the review. Stage one on the process was the searching of the above terms for paper titles. Stage two consisted of the screening of titles from the search terms. Stage three involved the review of full text articles screened for relevance. Finally, the reference sections of papers included were checked for additional studies.

2.1.2 Criteria for inclusion

The criteria for inclusion of the studies was as follows:

1. Published epidemiological, cohort or cross-sectional research studies
2. Study reported the prevalence or incidence of musculoskeletal injuries in golfers.
3. Amateur and professional subject golfers.
4. Studies published in the English language.

2.1.3 Results of methods

1014 studies were initially identified once duplicates had been removed from the search engines. Through the screening of titles and abstracts 23 articles met the inclusion criteria for review. Upon there 18 studies were removed leaving 16 studies to be included in the review when combined with additional consultations or snowball studies.

2.1.4 Study Quality

The studies were assessed using the quality assessment tool for observational cohort and cross sectional studies. (45) The assessment tool uses fourteen questions to give an internal validity evaluation of the study. The studies included were of overall poor quality with no study being able to answer >50% of the questions posed.

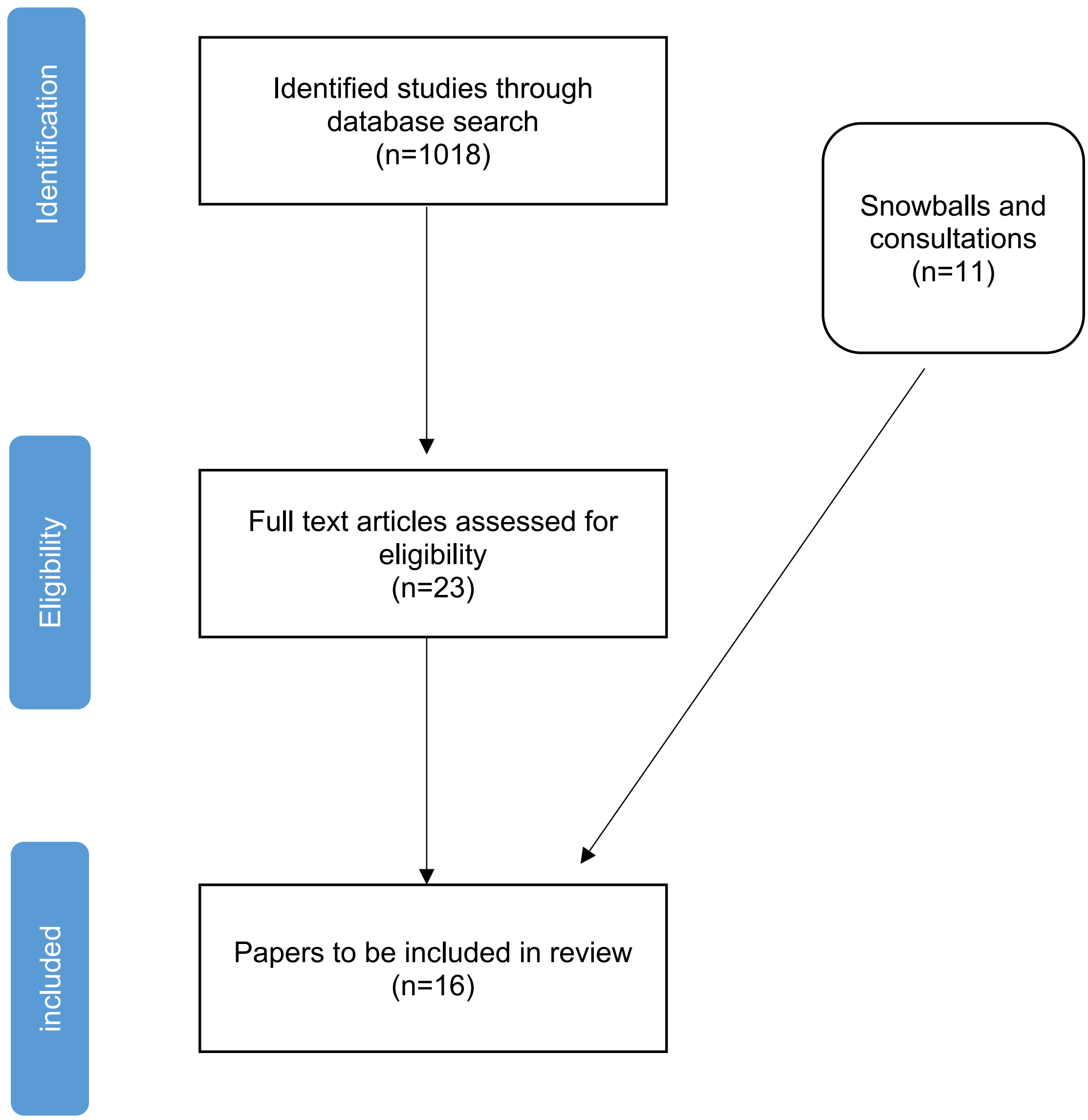

Figure 1, flow of literature search for injury in golf review.

2.2 Literature review discussion

Golf swing mechanics and overview for injury in Golf

The mechanism for golf injury has been researched by Cabri *et al.* (12) and Sell *et al.* (5) These authors reported professional players are subjected to regular competition and follow an intense practice schedule culminating in hundreds or thousands of swings a day which can lead to the observed increase in prevalence and quantity of injury per player. Cabri *et al.* (12) found that professional and amateur golfer's present differences in occurrence and site of injury, citing players habits as one reason for this. Risk of injury was found to be primarily down to two factors; a higher handicap and increase in age. Musculoskeletal changes that occur throughout the aging process lead to an increased chance of injury occurrence. One important finding of Cabri *et al.* (12) was that amateur golfers have an injury rate of 1.31 per year, whilst their professional counterparts average in excess of 1.9 and a prevalence of 88%. This was attributed to increased daily hours played, (21) leading to a greater volume and more exposure to traumatic acute and overuse type injuries, owing to the increase in hours played by professionals.

The biomechanics of a golf swing are complex with high forces being placed upon a multitude of joints. Given the repetitive physiological and biomechanical demands of the swing upon specific areas of an athlete's body it is logical to expect injury to occur at sites exposed to a high magnitude of force. The nature of injury for golfers is predominantly overuse (26) and commonly, the lower back is one of the most frequently injured areas of the body. Within amateur golfers, technical swing deficiencies are often a pre cursor for injury although this is less of a problem at an elite level. (26) During the golf swing, the lumbar region of the spine and its associated musculature are exposed to lateral bending and compression forces that caudally press down on the discs. These compressive forces are approximately eight times the body weight of the golfer. This, coupled with the torsion stemming from twisting and rotation of the spine is directly associated with the onset of lower back pain in less proficient golfers. (46) However, such instances can be somewhat negated through the use of a "classic" technical golf swing and the implementation of strengthening the transverse abdominals' muscle group. Lower back pain less common amongst professional golfers' , whom whilst not possessing a classic golf swing, tend to have fewer technical errors and often partake in strength and conditioning exercises with much time dedicated to the strength of the core and lower back regions.

A 2010 study by Smith *et al.* (13) collected data from 36 tournaments across a two year competition cycle (2005-6) centred around the Professional Golfers Association (PGA) European tour mobile physiotherapy unit. The total number of injuries rose by 25.6% from 2005 to 2006 with 'back region' injuries accounting for 66.15% of all injuries across the 36 events and 216 days the mobile unit was present at those events (Tuesday-Sunday of tournament weeks). Individually, specific areas of the back, namely cervical, thoracic and lumbar injuries increased by 3.5%, 63.7% and 31.6% respectively from 2005 to 2006. The recorded data from the mobile unit provides valuable insight into commonality and frequency of injuries at specific sites of the body of PGA European Tour professionals. However, the days lost (severity) of the injuries was not recorded, thus limiting the value of the data. Furthermore, of the total number of approaches by golfers to the mobile unit over the two years, 71% of all approaches (7087) were contacts made by players receiving massage, manipulation or stretching treatments with many of these being reoccurring within an individual player i.e. treatment for an injury was ongoing throughout a season or over two seasons. Finally, Smith *et al.* (13) categorised 92.7% of all contacts as minor, golf-related cases of joint or muscular conditions. This study was retrospective and self-reporting meaning there may have been some subjectivity from the subjects when reporting back and furthermore, the retrospective aspect may have meant that the subject's ability to recall accurate data may have been compromised. Despite this, the study does outline a range of data over a long period of time and provide context for golfing injury over more than one calendar year.

2.3 Back injury in Golf

The high occurrence of back injury's in golfers at a range of age and ability levels have been looked at in some depth within the general golf injury literature. (12,13) Lumbar pain was reported as the most common site for pain. (12) The incidence rate for cervical and thoracic pain was significantly lower than lumbar. Lindsay & Vandervoort, (47) carried out a review of causative factors and possible preventative strategies of lower back pain amongst all abilities of golfer. Lindsey & Vandervoort, (47) reported that findings have ranged from 18-54% incidence rate of lower back pain amongst golfers, as aggressive biomechanical forces are placed upon the lower back throughout the entirety of the golf swing including axial twisting and general trunk torsion. These risk factors were to be considered as significant for lower back pain. Furthermore, the findings of Hosea *et al.* (46) expressed the notion that the forces created by a golf swing can produce sufficient force output to potentially injure the lumbar spine, via either a single traumatic event or a more repetitive and long term build-up of pain through extensive repetition and cumulative load. As Lindsey & Vandervoort (47) concluded, there are many factors attributed to lower back pain in golfers ranging from overuse, poor conditioning and external biomechanical stressors on the spine. The preventative measures to potentially be applied to sufferers of lower back pain are as follows; swing coaching from an accredited coach, improved rotational flexibility, avoid extensive playing/practice and improved strength around the trunk region coupled with an extensive dynamic warm up routine prior to playing. (47)

Lower back musculoskeletal injuries are the most common complaint of professional golfers according to Hadden *et al.* , McCarroll *et al.* and Cabri *et al.* (12,25,48) but the high prevalence of such injuries cannot be definitively linked to golf volume alone. Subjective complaints were reported from ball strike to follow through. Additionally, greater thoracic flexion when addressing the ball was observed in those reporting pain. (12) Despite this, other researchers have found that golf activity was not always perceived to be the cause of lower back pain amongst subjects questioned and without a definitive objective diagnosis. Within the same study the biomechanical factors and forces on the lumber spine surrounding injury to the area were explored. Compressional biomechanical forces are applied to the lumbar intervertebral disks and the repetitive action of the golf swing are thought to be contributors to lower back pain as well as over rotating through the lumbar spine and abnormal abdominal muscle recruitment patters coupled with lower levels of muscular endurance. (47)

2.4 Hip injury in Golf

Hip Injury in high level golf has received little attention in the literature up to this point, possibly owing to the fact that hip injuries are far less common than lumbar spine or wrist injuries. Smith *et al* (13) reported 2.4% total injuries (2,328) were hip related. The paper offered no insight into why that was the case regarding mechanism for injury. Although previous literature has acknowledged the stability of the hip joint owing to the interaction of the head of the femur and acetabulum of the pelvis forming a synovial ball and socket joint, thus potentially lowering injury risk. Chronic musculoskeletal hip injury was highlighted by Gosheger *et al.* (4) with 7.7% of all chronic injuries in the paper being attributed to the hip joint. However, 63% of all chronically injured participants did not associate golf with causing their problems.

Acetabular labral tears have been documented in golfers by Zouzias *et al.* (49) Through the golf swing, rotational velocities place the hip joint and labarum under excessive stress. Despite this, the incidence rate of hip injuries remains very low (2.8%). Of those injuries, 78% are attributed to overuse with a statistically significant correlation between reduced hip internal rotation range of movement (ROM) and lower back pain thus suggesting that despite there being a low incidence rate of hip specific pain, some factors could cause pain elsewhere in the body. Other mentioned hip pathology in the literature includes femoral-acetabular impingement (FAI) with work carried out by Dickenson *et al.* (50) highlighting FAI pathology in a male professional golfing population. This study looked at non parametric data following completion of a self-reporting questionnaire, clinical and magnetic resonance (MR) examinations. 109 professional golfers took part in the questionnaires with 73 undergoing clinical examination and 55 MR examination. The results of the study showed 19.3% of male golfers reported hip pain with increased femoral neck angles and increasing age deemed to be significant predictors of reduced hip-related quality of life. Clinical examinations emphasised FABER impingement testing (FAI) was positive in 12 players (16%). Further different hip pathologies include loose bodies within the hip joint and hip arthritis though this is associated with older populations and less applicable to the elite professional.

2.5 Knee and ankle injury in golf

The knee is another common site of injury for golfers, (4,12) however according to Smith *et al.* (13) only 4% of PGA European Tour golf contacts were knee related. That figure has been estimated to be as high as18% in other relevant literature but Baker *et al.* (35) found that figure to be 9%. As with back pain, skill level, age and sex are not necessarily pre cursors for knee injury. (35) The compressive loads on the lead knee in a golf swing range from one to four times bodyweight (BW) at peak kinematic forces, Baker *et al.* (35) reported that the magnitude of loading appears to be independent of the club used. Upon review, the perception of low-load, low risk injury risk is not in fact true and a complex set of biomechanical stressors could lead to knee injury during the swing follow through. Such actions include the rapid knee extension of a player between 0-30°, high tibial rotation combined with large ground reaction axial torque, as well as strong quadriceps activity leading to high joint loading. (35) However, as this paper was a systematic review of previous literature, it was concluded that many past studies used the results of a single inverse dynamics study to bring about their results and this lead to an underestimation of the true magnitude of joint forces measured at the knee owing to the articulating surfaces in the joints being smooth and thus not creating a frictional force. The report of loads generated of the knee during a golf swing (320-440% BW) were similar to other higher intensity exercises, (35) consequently the net loads alone are unlikely to bring about traumatic injury. That said, when coupled with the rotational loading at lower flexed angles, these conditions could lead to repetitive injury, moreover with this more likely to be the case with players with prior knee injury history. (35)

The work of Marshall *et al.* (23) cited that the knee joints dependency upon ligamentous support as a potential internal risk factor for injury. Stating that the rotational stresses impart strain to individual ligaments of the knee in golf. With tibial torque and knee flexion angle identified as potential injury contributors, both are influenced by external factors such as ground surface characteristics and shoe-surface interaction. (23) In agreement with Smith *et al*. (14), Gluck *et al.* (15) concluded that single stroke loads were sub maximal compared to other relevant torques, therefore it seems unlikely that loads associated with internal risk factors of technique or anatomical structure would reach the required magnitude to induce an injury to the knee even within competition. However, the likelihood of injury may be increased on the practice range where the rest between strokes is drastically reduced due to pace of play and a short set up time for the next swing. Additionally, Lindsey e*t al.* (51) noted that generally, over a prolonged time period, athletes lose a percentage of the tolerance to sub maximal stresses which can potentially lead to an overuse injury. Though knee injuries have been covered in past literature (12,25,35) many of the studies are not conclusive regarding prevalence of injury and that further research on golf specific knee and lower extremity injury in general is encouraged.

Specific golfing literature on ankle injury in golfing populations is sparse. This is partly due to many ankle injuries within the sport being acute and traumatic. Zouzias *et al.* (49) acknowledges there being minimal literature on ankle related golf injuries although McHardy *et al* (26) attempted to cover injuries to the ankle joint during golf to some extent. Many of the injuries presented by McHardy *et al* (26) were secondary consequences to actions such as slipping or falling although golfers can sustain lateral ligament sprains as well as tendinopathies with the majority of such injuries requiring non-surgical intervention.

2.6 Upper Extremity Injury in golf

2.6.1 Wrist injury in golf

The wrist is another peripheral joint where injury occurs frequently. A PGA European Tour study by Hawkes *et al.*(52) was conducted at the 2009 BMW PGA Championship at Wentworth where 128 of 153 eligible golfers completed the self-reporting, retrospective questionnaire followed by semi structured interview and personal examination. The findings were reported that 30% of golfers at the event reported 43 wrist injuries. The leading wrist was the most common location of injury, with 67% of problems occurring at that particular site. Within the lead wrist, the ulnar side of the wrist accounted for 35% of such injuries with 87% of ulnar and 100% of radial-sided problems being on the lead wrist. Such data indicates a clear difference in injury of the different sides of the wrist. 20% of respondents to the questionnaire reported that a wrist problem had caused them to miss one or more tournaments, and 11% of respondents with a wrist injury admitted to the problem being ongoing at the time of the interview. One limitation of this study, as with many self-reporting retrospective questionnaires was that it relied on the subjects to accurately recall information. Despite this, unlike other similar studies, this study produced an 84% response rate, potentially due to the methodological design.

The specific swing pattern and known motion paths of the leading (non-dominant) and trailing (dominant) wrist enables an understanding of the mechanism for wrist injury within elite golfers. DeQuervian's tendonitis proved to be the injury that caused the greatest reduction in playing and practice time, whilst extensor carpi ulnaris (ECU) tendonitis proved to be the most common wrist injury of all of the players questioned. (52)

Although wrist injuries in golf are not particularly common in terms of their frequency, when they do occur, they can be traumatic in nature or in consequence. Wrist injuries are predominantly overuse injuries amongst amateur and professional golfers, with the wrist flexor and extensor tendons the main areas affected. (53) Tendonitis of the ECU tendon has also been observed within some professional golfers who reported pain at the top of the takeaway phase of the swing where the lead wrist moves into excessive radial deviation. Furthermore, the hyperextension and radial deviation of the bottom hand during the swing phase may cause impingement syndrome in the area. Given that many wrist injuries are overuse (inflammation, impingement), non-surgical intervention is often applicable although this can lead to an extended period of time away from golf. (53) In a professional environment this will lead to missed tournaments potentially affecting ranking and prize money earnings.

However, some traumatic wrist injuries can occur, although these are usually rare events caused by a unique set of circumstances, such as hitting a tree root resulting in a fracture of the hook of hamate. (4) Other acute traumatic injuries to the wrist can occur from a forceful sudden impact to the joint when striking the ground prior to the ball. This action may cause ECU tendon sheath disruption, (49) which recreates pain when the wrist supinates or ulnar deviates. Rest and potential splinting of the wrist are advised given this injury, but if symptoms do not improve, surgical intervention on the tendon sheath may be required.

2.6.2 Shoulder injury in golf

Shoulder joint injuries can occur as a result of the golf swing. The shoulder is the third most commonly injured area of the body behind the lumbar spine and wrist area for the professional golfer. (54) McHardy *et al.* (26) reported that between 8-12% of all golfing injuries are related to the shoulder however that number has been estimated to be as high as 17.6%. (4,55) High level golfers often sustain overuse injury to the shoulder through repeated swings over frequent practice sessions. (4) Injury type tends to differ and increased age is a key component of the Increased likelihood of injury. Kim *et al.* (54) further stated that generally speaking the lead shoulder (left shoulder on right handed players) is usually the symptomatic side (93%). (26) Within the same paper, 53% of players reported acromio-clavicular pain and golfers had posterior instability as well as the majority showing signs of a sub-acromial impingement. Pain was reported within the left shoulder at the top of the backswing. Acute traumatic injuries as well as some form of instability more common in the younger golfer, whereas middle aged golfers are often found to be symptomatic of sub-acromial impingement, gleno-humeral instability and rotator cuff disease. With regards to such injuries, competency in the understanding of the biomechanical kinematics of the golf swing can lead to correct diagnosis and treatment of the injury with non-surgical intervention being preferable, in spite of this, Kim *et al.* (54) summates that surgical intervention can also lead to a return to play at the same level as prior to the injury.

2.6.3 Elbow injury in Golf

Injuries to the elbow are less common in male elite golfers and have a greater prevalence in less skilled and female players. A tendency for some golfers to grip the club overly tightly has been observed to potentially cause strain to the elbow joint. (4) The lateral epicondyle is the site of most golf related injuries with 85% of elbow injuries in amateur players being found at that site by McCarrol *et al.* (55) despite pain in the medial epicondyle being commonly referred to as ‘golfers elbow.’ The reason for medial epicondyle pain is a sudden deceleration of the clubhead leads to a traumatic injury to the epicondyle such as hitting the root of a tree or the clubhead striking the ground prior to the ball. Overuse of the lateral aspect tends to cause injury with the latter having a higher commonality. (26) To combat overuse injuries of the elbow, the use of a brace or larger sized golf grips could be implemented. (26) In addition to this, non-surgical treatments such as non-steroidal anti-inflammatories (NSAID’s) as well limitation of play can be implemented to reduce lateral epicondyle pain. Once decreased, a series of stretching and forearm strengthening exercises can be prescribed in conjunction with some therapeutic modalities’ as an effective treatment (49). Besides the aforementioned papers, there is a sparsity in the literature of golf related elbow injuries. Much of the research regarding the mechanism for injury and management plans is within the domain of racket sports as the literature accessible covers the subject of sporting elbow injuries in much greater depth.

2.7 Chapter conclusions

In summary, authors such as Cabri *et al.* (12) and Sell *et al.* (5) have investigated the relationship between high level golf and injury. Conclusions reached include a heightened risk of injury for highly skilled players owing to more practice and competition time compared to their less proficient counter parts. However, professional players appeared to obtain fewer injuries that are caused by technical swing deficiencies. (4) Various authors have looked at a mixture of category players and where injury may occur, including the back, knee and hip. (23,47,50) Smith *et al.* (13) observed back injuries to be the most common amongst professional golfer's whilst knee and elbow injury were less prevalent in the same population. (30) Due to the lack of golf specific literature investigating the relationship between load and injury in golf, conclusions between the two are difficult to draw and require extensive further research upon this topic.

Chapter 3

Table 2. Terms and definition's relating to training load.

Term	Definition
Total Training load	*Total Training load is the sum of all load carried out by an athlete.*
Internal load	*Internal load is the relative physiological and psychological stress imposed on an athlete* (56)
External load	*External load is defined as the work completed by an athlete, measured independently of their internal characteristics* (57)
Absolute workload	*Absolute load is the total load of an athlete applied to a short period of time, most commonly a time frame of one week.*(8)
Relative workload	*Relative workload is the total workload for a week expressed against the total workload for a period of time immediately prior to that, this is usually the four previous weeks. (10)*
Acute workload	*Acute workload is the value given to the current time frames work (fatigue component)* (8)
Chronic workload	*Chronic workload is the value for workload completed over a longer duration (fitness component)* (8)

3.1 Literature Review on Training Workload Monitoring

LM has been implemented in a sports such as Rugby, cricket and football over recent years, (8,37,58) to observe the loads of athletes on a daily basis with the premise that the collection of specific data taken daily over a period of time can lead to visible patterns. Injury prevention is at the forefront of why workload monitoring occurs within many sports, (34) as the injury will impact upon an athlete's opportunity to be successful. With golf, however, there is little evidence to suggest LM is being carried out even at an elite level. Other aspects of world class performance such as strength and conditioning programmes and sport science intervention are being undertaken and are seen as being fundamental to improvements in sport specific physical characteristics, (5,6,59) yet golf LM remains absent across the sport. With many golf injuries being overuse related, (12,21) and seemingly little effort to try to track the loads of golfing athletes, it appears logical that LM should be implemented into the schedules of golfers as a preventative step to try to decrease the amount of overuse injuries caused by golf practice and competition performance.

LM at a high performance is a necessity as players try to find a way to perform optimally throughout the season, whilst remaining injury free. This requirement has been documented and the first attempt of research has been carried out. (27) This literature review will examine the current guidelines on the monitoring of training loads (TL) from other sports and how the principles applied to those sports may be applicable to golf.

Training LM, is extremely important for an individual or group of athletes to increase the likelihood of optimal performance at the correct time within an elite level sporting discipline. (33) Given that there is a visible link between training load, injury and illness, training LM is essential within high performing athletes to give the best chance of them remaining injury and illness free throughout training and therefore allowing for ideal physical preparation prior to sporting performances. To a certain extent, training LM has been implemented within sports such as rugby, (22) cricket, (39,60) and Australian Rules Football (AFL), (40) over recent years and from the specific literature produced, some clinical hypothesis have been confirmed surrounding training load and consensus formed by researchers. (34) Drew *et al.* (33) performed a systematic review of TL looking at the findings of researchers across multiple sports. With no papers being presented relating to golf in the review, there appears to be a lack of literature investigating TL in golf.

Firstly, it must be established what constitutes ‘training load’ and then the individual components that encompass training LM. TL is broadly divided into ‘internal load’ and ‘external load’. Internal loads may be explained as an athlete’s perceived or actual effort in response to a training stimulus such as actual Heart rate (HR) or their perceived effort, Rate of Perceived Exertion (RPE). External load is defined as the measure of work undertaken by an athlete such as distance travelled or weight lifted. (22) Internal loads are the response to the external load placed upon the athlete and can be measured by means of HR, HR:RPE ratio, biomechanical, hormonal or immunological assessments. (56) A 10 point RPE scale is the most commonly used internal load measure and is usually multiplied by time taken to complete the task. (22) Despite this, the reliability of the RPE scale has been questioned when assessing perceived exertion (61)

Total load (internal and external) is then primarily analysed via two means. Absolute and relative workload. (33) Absolute TL is the sum of all training, throughout a set duration (24 hours or 7 days). Relative workload is the TL of a given time period (usually 1 week) then expressed against the TL of the previous week. This can then be replicated across an entire training block. This relative load can be enumerated as a percentage of previous weekly loads and was originally introduced by Bannister & Calvert, (28) to account for the workload of athletes in the acute (fatigue) and chronic (fitness) stages of a training period. Relative workloads allow for the application of progressive overload as well as comparing training levels when in a similar pre fatigued state throughout training.

Following on from this is the final aspect of training load where 'acute' and 'chronic load' are considered. The acute training load is typically the load for a current 7-day period, where the chronic load totals a 28-day block with each weekly average also stated to compare to the most recent acute phase of training. This 'training-stress balance' (TSB) has since been modified into an 'acute:chronic workload ratio' (ACWR) given the measurable factors. (8) From this, the injury risk of an athlete can be monitored with internal and external loads used as a measure. Subsequently it is important to note the findings of Hulin *et al.* (8,37) are not complete quantification of loads and therefore may only explain a partial quantification of injury risk. That said, the concept that the training load of the past 7 days must reflect the work carried out over the past month otherwise an increase in injury risk is observed cannot be ignored.

Recently, a number of other sports have implemented a training load monitoring system for training and or competition at a professional level (22,34,62) with particular attention being paid to the association between training load and injury risk. Over the past five years, research has been published with a collection of subject experts collaborating to produce and International Olympic Committee (IOC) consensus statement on training load, injury and illness. (41,63) It has been the aim of strength and conditioning (S&C) coaches, physiotherapists and coaches alike to prescribe athletes, individual or in a team environment, a training programme physically challenging enough to improve fitness and physical characteristics applicable to the specific sport without increasing injury risk. This 'training-stress' balance has since been amended to become the concept of an ACWR conceptualised in the works of Hulin *et al.* and Gabbett *et al.* (8,64) This ratio depicts the acute TL of the most recent weeks training and compares with the chronic physical output of the individual athlete over the past four weeks. Whilst this concept is used in multi-faceted physically demanding sports such as AFL, rugby league and Gaelic football (GAA), golf does not require the physical exertion of these sports. This means that the fundamental principles of training and components linked to performance cannot be directly transferred over.

However, the principles of strength and power training used within these sports can be applied to golf concerning the improvement of golf specific physical characteristics. Moreover, this ACWR could carry over into looking at external loads in golf relating to balls hit over the acute and chronic time periods.

Detailing some of the findings of the ACWR rationale occurs over a series of studies. (8,64,65) One consistent theme throughout the papers is the importance of progression and systematic increase of workloads following on from each acute phase to therefore increase the average chronic workload capacity over a period of time. High chronic workloads were associated with reduced injury risk (8) whereas ‘spikes’ in acute load relative to the chronic workload were associated with an increased risk of injury. Additionally, the predictive ability of this approach yielded a positive prediction of likelihood of injury as high as 70 times. (66) Expanding upon this, Gabbett *et al.* (65) demonstrated a correlation between greater injury rates and higher training workloads. Contrary to these findings, the benefits of training (such as well-developed physical attributes) may provide a level of tolerance that potentially provides protection from injury risk.

Conversely, a high proportion of injuries were associated with a prompt alteration in acute training load (>10%) increase compared to the previous week, (8) therefore practitioners should consider limiting training load increases to <10% from one week to the next as a preventative measure to avoid injury. A well-structured programme that culminates in a gradual progression to high workload makes for durable athletes whereas steep acute increases in workload results in a higher probability of injury. (64) This may be true within the game of golf as the principle findings of increasing and decreasing injury risk within other sports may be applicable to any form of training workload within a sporting context as in general.

Within the acute chronic workload relationship, a ratio of 0.80:1 - 1:30:1 represents optimal weekly workload for reducing injury risk. This is referred to as the 'sweet spot' for TL volume whilst yielding the lowest percentage of injury risk for an individual athlete. (65) Practically speaking, ACWR can be monitored every day for each athlete although this seen as optimal TL is not a fixed 'golden' set of numbers and will not be applicable to all athletes across all sports.

Subsequently, a host of differing factors should be considered when working with an individual athlete including prior training and injury history. This will have an influence on their training-load tolerance and injury risk. Despite the conceptualisation of the ACWR, (8,37) some problems do occur with the physical application of the TL volume of athletes. Practitioners are responsible for data collection of individuals within a team, the quantity of raw data Is extensive, therefore, daily inputting of data is paramount for up to date data regarding TL.

Injury incidence and TL have been evaluated in depth by various authors, (40,64,67) Drew *et al.* (33) performed a meta-analysis on the literature subject. Throughout 31 studies meeting the inclusion criteria of the systematic review, increased workload was related to subsequent injuries in 90% of the studies. Hulin *et al*. (37) reported a TSB of 200% gave a 3.3 relative injury risk and this risk was sustained for 3-4 weeks. Further findings indicated that internal loads (RPE x Duration) were twice as likely to predict injury as measuring external load only within the same athletic population. Injury risk is also linked with current training load reflecting recent historical workloads, (8) and highlighted that careful consideration of training session load needs to be applied when calculating acute loads when based against recent chronic loads. It has also been found that lower levels of accumulative load lead to an increase in injury risk (33) and that injury tolerance is built up over a larger chronic timeframe. This fits the findings of Hulin *et al.* (8) whereby higher chronic workloads combined with relative loads and not cumulative loads, protect against potential injury risk when acute loads meet that of the chronic workload. Regarding training load and illness, Anderson *et al.* (68) found there to be a positive relationship with 42% of illnesses associated with a preceding spike in workload of >10% compared to the previous week.

Within the current golf specific literature relating to training load monitoring, the only research to the authors knowledge is that of Williams *et al.* (27) The aim of the work was to establish content validity and then feasibility of a golf specific load monitoring tool and following a literature review 36 items were selected for potential inclusion in the golf load monitoring tool (GLMT). However, the study lacked any expert input in the initial conception of the 36 golf related items and thus perhaps would have benefited from a different approach to looking at possible inclusion criteria for a GLMT.

The methodological short comings of the study by Williams *et al.* (27) could have been improved with a successful application of the Delphi method. A Delphi method has been described and defined by Dalkey & Helmer, Linstone & Turoff and Okolie & Pawlowski, (69–71) and originated as a technique to obtain the most reliable consensus from a group of experts, in essence it is a group knowledge acquisition tool. (72) The first step in a delphi method is to define the problem. (73) In the case of the study in question the problem was that there is limited research and consensus on training load monitoring in golf within academic literature. From there, identifying and inviting experts to communicate and solicit ideas is the next step. However, as there was no consensus on golf load monitoring, the communication with the experts by Williams *et al.* (27) should have been on creating a consensus rather than consulting the experts on the 36 items that the authors had created. Therefore, the study lacked appropriate expert knowledge to be taken into rating the ideas, which is the final step in a delphi prior to the final review. (73)

3.2 Chapter conclusions

In summary, various authors have researched training load monitoring across sports such as rugby, football and cricket. (60,67) Some of the methods being applied such as the acute chronic workload ratio, (37) may be transferrable into the sport of golf. Furthermore, the fundamental principles of the quantification of workload remain the same irrespective of athlete or sport. The applicational difficulties may lie in how the knowledge gathered in previous research can be applied to golf and the sport specific aspects of golf practice. Subsequently, it is clear that from the limited amount of golf specific workload monitoring literature, further research needs to be undertaken. The study by Williams *et al.* (27) provides a reference to work carried out in the future. However, some of the issues with the study, such as the poor response rate and requirement for the opinion of an expert panel in the creation of a survey to come up with a consensus on inclusion items for a GLMT, cannot be overlooked.

Chapter 4

Table 3. Definitions and terms relating to qualitative research

Term	Definition
Delphi process	*The process of constructing a group communication with experts to find a consensus on a particular problem. (70)*
Epistemology	*Is the theory of knowledge within our world and the assumptions and beliefs surrounding it. (74)*
Ontology	*Ontology is the philosophical study of nature and reality, it is a branch of the study of metaphysics (75)*
Reflexivity	*Reflexivity is the self-awareness of intersubjective dynamics between a researcher and a piece of research. (76)*
Research Paradigm	*A set of beliefs or metaphysics that make up the world and all things within it. (75)*

Qualitative Methodology

4.1 Introduction to qualitative methodology

Delphi is a process utilised in qualitative research to gain opinions from a panel of experts using a consensus method without the need for face to face interaction. (70) During this research, a series of semi structured interviews with a multi-faceted expert panel of practitioners was constructed with the outcome of these interviews forming the foundation of possible inclusion topics for a golf load monitoring tool.

4.2 Theoretical Framework

Delphi may be characterized as a method for constructing a group communication process so that the process is effective in allowing a group of individual's as a whole to deal with a problem. (70) This structured communication allows individuals to feedback information and knowledge without the direct confrontation and interaction between experts. This is advantageous for the expert in question and aids in the gradual formation of a considered opinion. (69) A full flow of the Delphi method can be observed later on in this chapter (figure 2.)

The current study implemented a variation of Delphi method, whereby a group consensus or order of importance was observed through ranking the individual topics of most to least important regarding a golf workload monitoring tool. However, the first step was to conduct separate literature reviews on training load monitoring and injury in golf to gain sufficient knowledge of the topic and assess the requirements of the study. Following on from this the semi structured interviews were conducted in order to form a consensus on potential inclusion topics for a golf load monitoring tool. As such, this preceded any questionnaire's that are present within many Delphi method study's owing to a lack of consensus opinion regarding the inclusion topics for a golf workload monitoring tool.

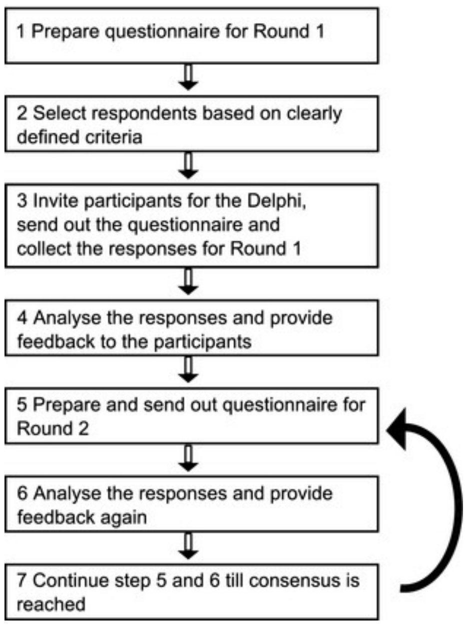

Figure 2. flowchart representing the Delphi method. (77)

This variation of Delphi method was described in detail by Schmidt *et al.* (78) and by encompassing many aspects of the Delphi method, the current study had a platform and basis for a consensus through an expert panel with an objective approach to research gathering that did not depend on sample size and statistical power rather group dynamics. This lead the content to arrive towards a consensus opinion on the inclusion topics for a workload monitoring tool in golf. (71)

The representativeness of a Delphi sample lends itself to being considered as an independent meeting of experts without the interaction and potential influence of external viewpoints to shape the narrative. This form of information gathering is of particular importance given that the general population, or even a subset of that population may not be sufficiently equipped to answer the difficult question presented to the researcher. (71) The breadth of professional disciplines encompassed within the interviews (coach, player, physiotherapist, S&C coach, doctor) ensured a wider collective wisdom and overall base for a more complete and comprehensive decision making. This ensured the appropriateness of inclusion topics for a golfing workload monitoring tool, (72) and the anonymity of individual interviews ensured the obstacles of groupthink were a non-factor. (70,79) As stated by Hsu & Stanford. (80) choosing the appropriate subjects is the most important step in the entire process owing to its directly relating to the quality of the results produced. The participants selected had been involved in high level international golf within the past two years.

One weakness of Delphi is a lack of theoretical framework. Delphi as a research methodology has been presented in various forms including; study, survey and technique, (71,81,82) and the broadness of use and lack of singular concise technique has led to the formation of that perception. Nonetheless, a framework can be used that generally applies to most Delphi techniques to some extent. Another advantage of the Delphi technique is the focus on the quality of the subjects included in the research as well as the onus being on ideas rather than individuals. Despite this, there are some shortcomings of the process such as the time consuming nature and complexity of interpretation of information given. (80)

Habibi *et al.* (72) outlined a framework consisting of an initial application requirement gathering stage then leading onto the composition of a panel of experts, the collecting of expert opinions to then determine the presence or absence of a consensus. If there is a consensus, then a statistical group response is formed. If not, the framework states that it refers back to the regathering of expert opinions until a consensus is formed.

With regards to the composition of an expert panel, the size should be adapted to the needs of the study. In the case of the current piece of research, it was important to include a variety of experts from differing fields to allow for the capturing of opinions and points of view from the varied practitioners involved in elite golf. In addition to this, where possible, more than one expert from each individual field was interviewed allowing for greater validity of opinions. What is widely agreed upon is the inclusion of multiple specialties' or specialists and that Delphi subjects should be highly trained and competent within the specialized area of knowledge related to the target issue. (80)

In conclusion, the Delphi technique is a research approach with the aim of gaining a consensus through feedback of participants who have a requisite level of expertise within key areas or topics of conversation. One weakness of the technique is the relative lacking of theoretical framework given the wide-ranging presentation of Delphi form (survey, study, method). Conversely, access to the Delphi technique is simple, (72) and it represents an important method for data collection with a wide range of applications for those wishing to gather information from others immersed in the topic of interest (80).

4.3 Reflexivity

As with when any qualitative research is carried out, there is a requirement for the role of the researcher to be reviewed throughout the process of research conception. To some extent, self-analysis and reflexivity are found to be missing in research. The content of research is the main focus rather than how the content came about. (83) Etymologically, reflexivity means to “bend back upon one’s self” but in terms of research this definition can be translated to one being thoughtful and self-aware of the intersubjective dynamics between researcher and research. (76) It is accepted that in the qualitative paradigm, there is the possibility for influence on the research by the researcher through their actions based on previous knowledge and experiences (84) and therefore a reflexive stance and the consciousness of the researcher to remain as objective as possible is an important aspect throughout the research process.

Finlay & Gough, (76) state that reflexivity can be a valuable resource for qualitative researchers as it helps them to examine the impact and perspective of the researcher as well as allowing them to evaluate the entire research process, method and outcome. Multiple aspects of reflexivity are required to enhance the thinking and evaluation of qualitative research such as changing power dynamics within an interview as well as the emotional and subjectivity involved. (85) Subsequently, it involves being acutely aware of the ways that research participants are influenced by power outside of the immediate interviewing context. Of course, as many researchers have observed and quantified, adopting and applying a reflexive stance throughout a research timeframe is no easy task. (86) Conversely, it is important to be self-aware of potential biases throughout the research process and avoid them as a researcher to ensure that data is as objective and therefore valid as possible.

Throughout the research piece, I was mindful of the fact that I was not an expert nor a regular participant of the game of golf. I hadn't experienced many of the points of discussion first hand, this also meant that I couldn't just take the content that I came across discussing injury or workload in golf at face value and there needed to be an analytical and critical focus to the assessment. When interviewing the expert panel, it was a conscious decision for the interviews to be semi structured to ensure the presence of some kind of topical framework for consistency purposes. However, there was the scope for the individual experts to discuss topical content from their points of view and then add in additional knowledge to areas that I had perhaps oversighted or undervalued in their opinion.

Many of the original, generic questions surrounding a particular topic for discussion on golf workload were open in their delivery to allow for individual interpretation of the question. Following this, there were potential prompts and topical keywords that could be applied to the discussion if deemed necessary and the trail of discussion was going off on a tangent. Successively, I was conscious of not highlighting the opinions of other experts throughout the interview as such the interviewee may have felt a pressure to agree or disagree with another on a topical viewpoint. This potential bias may therefore impede a true opinion or viewpoint being expressed within the interview.

It was also important, that I did not allow for my position as a research student to guide my questioning and imply a certain contextual opinion that I would want expressing from the expert. If this had occurred, themes and results could have been altered when it came to the data analysis. Furthermore, I was mindful of the fact that any consensus outcomes amongst the expert panel was to be natural. This would guard against producing results and themes for the sake of the research as doing this would falsify the objectivity of the research piece that could affect the broader research area in future references to this work.

Finally, reflexivity extends to the analysis of data not just its collection. During data analysis a researcher needs to be able to accept and acknowledge their own influences and assumptions whilst simultaneously analysing their data. Probst, (87) remarked that reflexive researchers are self-aware and ‘in essence gazing in two directions at once, focussing on both their own field of study and becoming aware of their own assumptions and attachments.’ This is certainly applicable to the current study as in qualitative research, interview data is highly dependent on the researchers’ interpretation of the participants’ terminology and non-verbal aspects of interaction to accurately analyse the entirety of an interview. Given the fact that I was comfortable with golf specific terminology, and at no point felt like my knowledge surrounding the area was inhibiting my ability to act as the instigator of conversation within the semi structured interviews, I believe that I was reflexive throughout the interview and data analysis process.

4.4 Research Paradigm

A paradigm has been defined as a ‘set of basic beliefs or metaphysics’ and a worldview that defines the nature of the parts that make up the world including its individual’s and relationships. (75) Paradigms are normative and are formed through socialisation and discussion and inform researchers how to carry out tasks without large amounts questioning or reflection. This is both a strength and weakness of a paradigm as, in essence, they are mutually self-reinforcing in making action possible and hiding reasoning and unquestioned assumptions within the paradigm itself. (84)

Most qualitative approaches can be traced to philosophical traditions with differing epistemological (theory of knowledge and then assumptions and beliefs surrounding it) and ontological (philosophy of existence and what that means) assumptions. Qualitative research often emerges from the ‘interpretivist’ paradigm, (88,89) with the summations of the paradigm including a relativist ontological stance with inter-subjectivity constructed through the understanding that reality is developed through social experience. (75) However, with the Delphi method, the hybrid epistemological status owing to a mixture of qualitative and quantitative features leads to a constructivist paradigm being adopted. (90)

The constructivist paradigm applies a relativist ontology as realities are formed of multiple intangible constructions in the mind and are socially and experientially based. (75,91) These constructions are form and content dependant on the individual person and are not more or less true than other ontologies, simply less informed and are alterable. These characteristics make constructivism distinguishable from nominalism and idealism. (75) In addition to this, constructivism's relativism assumes multiple social realities that are the product of human intellects but are not rigid and may change as their constructors become more informed and sophisticated.

Furthermore, constructivists often adopt a subjectivist epistemology by acknowledging that we cannot separate ourselves from what we know about ourselves and the world. This applies to research and our beliefs about the outcome of what we encounter throughout the research process too. Subjective interaction is used to access the realities of the responder, the responder only where findings emerge through dialogue and the dialogue between researchers and the respondents is critical in the subjectivist epistemology as this process leads to a more informed and better understanding surrounding a particular research subject. (90) The investigator and subject are assumed to be interactively linked with the 'findings' being the creation of this interaction and therefore, literally being created as the investigation proceeds. (75) However, the interpretations of such dialogue are based in a particular moment and context within a unique situation, therefore such interpretations are open to re-interpretation through conversation or review and this aspect of the epistemology is something that I had to account for when carrying out the analysis of the raw data that stemmed from the semi structured interviews.

4.5 Chapter conclusions

In conclusion, there is seen to be a potential lack of a theoretical framework in the Delphi method owing to its presentation in various forms. Conversely, the work of Habibi *et al.* (72) did outline a framework and this will be utilised in the work of this current research piece. As Finlay & Gough, (76) stress the importance of being reflexive for a qualitative researcher and how reflexivity enables critiquing of the researcher as well as the research, a key component of being truly objective throughout a process. As the researcher understands this and its application to all portions of research, a reflexive approach is adopted to the semi structured interviews as well as the data analysis. A constructivist research paradigm was adopted for the current research piece owing to the nature of the research piece and its similar methodological structure to a Delphi method.

Chapter 5

How should golfers monitor training load?

5.1 Introduction

Golf, as a global sport, has huge popularity across multiple continents. However, the majority of its 55-80 million players reside in the United States and Europe where the two major world tours (PGA tour and PGA European tour) are based. (1,2) Within these tours, elite players compete for vast sums of money with sponsorship and commercialism, (92) playing a major role in ever increasing prize money, 'the cost' of players missing tournaments as well as valuable practice time through injury has never been higher. The demands placed upon professional golfers is evolving too, increased professionalism and recognition of the importance of having an athletic lifestyle for the very best in the game means more players are combining technical training with physical training. (93,94) Improving performance through these avenues means demanding more from the body in the process as it facilitates an increased workload of the current professional. Technical practice is becoming more rigorous too as professional golfers typically hit >2000 balls weekly with 73% striking above 200 per day on average, (20) and with the game evolving over time so too has the 'modern golf swing' which brings about differing biomechanics. (95,96)

Various authors such as Cabri *et al.* (12), McHardy *et al.* (26) and McCarroll *et al.* (30) produced work that concluded that overuse injuries are commonplace in golf with biomechanical and technical factors deemed to be potentially causal. With this in mind, it is logical to investigate golfing load as a possible intervention to better understand and potentially lower such overuse injury rates.

It is well documented within other sports that load monitoring has been successfully implemented as a method for observation of daily internal and external stressors to athletes with the goal of load monitoring leading to fewer overuse related injuries. (8,65,97) Ideal training in any professional sport may be difficult to attain but is always the goal. Athletes and practitioners endeavour to train as often and as optimally as possible to maximise the chance of success within a sport, whilst remaining injury free to enable competition to take place. The sport of golf is no different, nonetheless load monitoring is seemingly absent even within the upper echelons of the game and this conclusion can be drawn from an obvious absence of literature regarding this subject, with the exception of the recent work of Williams e*t al.* (27)

As previously referred to, the study of Williams *et al.* (27) included load specific physical characteristics of golf and training activities, recovery, sleep, travel and golf performance. 21 of 75 (28% response rate) contacted 'experts' completed the survey for inclusion items, this was an abnormally low response rate, thus potentially lacking a diversity in opinion as well as reliability. Furthermore, a low number of initial participants has a greater impact on effect size and the overall statistical power. Within the paper the reasoning for the low response rate was not addressed.

The inclusion criteria for items including physical and golf training activities, recovery, sleep, travel and competitive performance golf was set at achieving at least a 78% agreement per the work of Polit & Beck. (98) The issue with this approach was that prior to engagement with the 'expert panel', the 36 items were selected by the authors following a literature review on golf and load monitoring. There was no expert panel consultation for the initial items to be sent, thus potential inclusion items may have been missed prior to the creation of the survey. Furthermore, once consulted, the expert panel had no input in additional items, their task was to rate each item on a Likert scale. (27)

Following communication with the expert panel 23 items were selected for inclusion in the 28-day pilot testing of the GLMT. To establish the feasibility of the GLMT 20 high-level golfers (with a world ranking and considering competitive golf as their main occupation) from Australia were recruited to participate in the feasibility study. Thirteen of these completed the study (65%) where daily completion from each participant occurred for 28 straight days via an excel spreadsheet, with perceived exertion and other measurable items noted. Following this, a feasibility survey was completed by the participants.

The study carried out was had two parts, investigating content validity and feasibility, Some results of this biphasic study were initially inconclusive for the content validity phase regarding golf practice, with distance to target (42.1%), grouping of clubs (36.8%) and individual clubs (15.8%) falling drastically short of the 78% required agreement. To clarify the matter, 21 experts were contacted but only six responded (28% response rate) so the 83% agreement reached on 'distance to target' required for inclusion was of a very small sample size and discounted the 15 experts whos opinion wasn't given. RPE was considered to be an appropriate method of analysing physical training but not for golf specific practice or competitive play. (27) This came from three responses and no reasoning was given for the unsuitability of RPE as a golf specific practice or tournament measure. Further to this, no appropriate measure was put forward.

Regarding feasibility, the perceived time to complete the GLMT daily had substantial variance amongst participants 5.0 $\pm$ 2.0 minutes each day completing the GLMT however this was not statistically different to the players perceived feasibility limit. All 13 players stated that they would choose to use the tracking tool long term therefore implying a willingness and engagement for golf specific load monitoring going forward with a smartphone interface being the preferred option. Summarising the study of Williams *et al.* (27) the paper provides a start point and reference for the work being undertaken by the current researcher as well as helpful insight into the procedures carried out to create a GLMT. Further refinement and improvement may be possible by the current researcher by identifying weaknesses or potential procedures that could be done to improve the final outcome.

Clearly, further research into golf loading is required and whilst the work of Williams *et al* provides a starting point, many of the parameters outlined within the paper were time based and much of the quantifiable data was perceived by players which may have some inaccuracies if compared with real data taken. As a final footnote, players were not involved in creating the content validity of a golf load monitoring tool thus not fully maximising the broad range of skillsets and insight to approaching a Delphi method as outlined by Okoli & Pawlowski. (71)

Given this, the current qualitative study was constructed with a varied expert panel of golfing practitioners and professional golfer's alike, with the selection criteria being all currently involved in the game internationally or having been so within the past two years. The representativeness of a Delphi sample lends itself to being considered as an independent meeting of experts without the interaction and potential influence of external viewpoints to shape the narrative. This form of information gathering is of particular importance given that the general population, or even a subset of that population may not be sufficiently equipped to answer the difficult question presented to the researcher. (71) This is heightened by the fact that there is limited literature regarding golf load monitoring and thus without a consensus opinion on how to approach such a new problem, the opinion of a variety of expert practitioners who experience first-hand the applied problem in question seems a logical place to begin.

Factoring this in, this piece of research used a cohort of expert panels across a breadth of fields within professional and international golf to confirm a combined insight into the particular problem presented by the research piece. Within this, a comprehensive process for the inclusion criteria was enabled owing to the harnessing of the Delphi method with anonymity of individual interviewees ensured and the obstacles of group rethink being negated. (70,79)

5.2 Methodology

5.2.1 Ethical approval

Prior to data collection, an ethical approval application was submitted to the University of Essex ethics committee to ensure that the study would be conducted in conjunction with complying to the University's ethical standards. Once this application had been approved, eight experts were contacted and took part in a semi structured interview to discuss a range of topics related to golf workload. All interviewees were either currently employed by, or had been employed at an International level within the game of golf in the previous 24 months.

5.2.2 Participants

The study participants for this Delphi method of semi structured qualitative interviewing were selected via the use of purposive sampling, adhering to other similar qualitative methodologies (75,99). Eight subjects, between them representing the fields of; golf coach (1), professional golf player (2), strength and conditioning coach (2), physiotherapist (2) and doctor (1), (all eight male) agreed to participate. The inclusion criteria for these participants was employment within International Golf (working with national teams or within an international golf tour) currently. With this in mind, these participants were selected due to their experience within professional golf and were viewed as an expert panel of individuals surrounding golf load monitoring. Selection ensured the representation of a diverse conglomerate of people who made up the support system of a professional golfer as well as the thoughts of a professional golfer themselves. The diversification of the participants was decided upon to create a broad band of expert knowledge and opinion surrounding golf load monitoring as golfing load is a universally present aspect of their profession.

5.2.3 Procedure

The procedural method of this study was comprised of two distinct stages, a Delphi method interview phase and an analysis of the interviews to form the results. The interviews were all carried out via the use of a video audio device (Quick time player) and a webcam meaning time efficient interaction and the extraction of data with difficult to reach groups. (100) Firstly, as the area of research is largely unexplored within the current literature, a consensus surrounding golf monitoring is yet to be established. This forms the reasoning for the use of the Delphi method as a pre cursor to creating a consensus finding. As such, eight participants were invited to partake in a singular semi structured interview following their verbal consent to discuss relevant topics regarding a golfer's schedule and components of their profession that they undertake on a daily basis.

Each interview began with topical statements made by the interviewer as a guidance for discussion. These subjects included; golf practice and competition volume, sleep, strength and Conditioning sessions and injury. Questions or statements put to the interviewee were open and the conversation was dictated by the interviewee's. The participants were encouraged to evaluate their own thoughts and talk in depth around as many characteristics of a golfer and their load as they could, including fields not within their scope of practice i.e. measurement of golf volume from the standpoint of a physiotherapist. The purpose of this was to examine the thought process and depth of opinion within individual aspects of golf loading, not just the inclusion of the opinion of the experts in their specialist field. In addition to this, certain quantifiable aspects surrounding each topic were discussed and how best to measure specifics of golf loading based upon their practice-based evidence within the game of golf. Practice based evidence is defined as the use of clinical expertise and synthesis of evidence obtained in a professional setting to create an opinion or hypothesis on a certain subject. As these conversations developed, participants were reminded that there was no right or wrong answer to any of the topical questions being put forth to them and if they had no opinion on a subject or could not give one then this was completely acceptable too. (101)

Furthermore, following the completion of discussion on the topics asking for the interviewee's opinion, the participants were given a platform to discuss any other areas not previously highlighted in the interview that they believed were an important part of a 'golfer's load'. This additional part of the interview was included to safeguard against any undiscussed features of golfing load that a particular expert deemed to be important to the topic remaining absent from the final interview transcript. Upon completion of all discussion regarding the topics deliberated during the interview process, the participants were then asked their opinion on the maximum amount of time they would expect a professional golfer to spend filling out information included within a workload monitoring tool to gauge a representation of the possible content of a tool and the depth of information a golfer would willingly input daily. The final stage of the semi structured interview involved the interviewer listing all of the topics discussed throughout the interview and asking the participant to rank the topics from most important to least important for inclusion in a golf load monitoring tool, thus giving a rank order from the individual to be used as an overall gauge of possible inclusion topics.

5.2.4 Analysis

Firstly, the semi structured interviews were individually transcribed to begin the data analysis. The analysis of the data collected was then completed via examination of interview transcripts to ensure content familiarity. From there, topical outlines were noted in order for patterns to be formed. This lead to the grouping of similar opinions across all data sets and the categorising of themes to be presented as the results of the interviews. A thematic analysis of the data collected was used per Braun & Clarke, (102) owing to its accessibility, theoretical flexibility and how it lends itself to inexperienced qualitative researchers as was the case with this study. The 'themes' in this case were interviewees opinions or statements that directly related to the topic of golf load monitoring and followed some sort of patterned response across the board in a number of responses. Because of the nature of the research, there is no definitive question to what constitutes a theme and the coding of a theme by the researcher requires researcher judgement as it is unlikely that a theme will consistently appear in equal prevalence throughout the analysis process.

Braun & Clarke, (102) state that some flexibility is prudent when a researcher is trying to establish and identify a theme within a data set and that there are particular phases to the process of a thematic analysis. These phases are applicable to all thematic analysis but not unique to it and add a consistency and rigour to the thematic process. Firstly, all data must be familiarised with the researcher through the transcription process (1). From there the initial coding (2) of the transcribed data takes place. In this instance, the maxQDA 2018v2 model was used to aid the researcher in the initial coding in a systematic fashion. Once initial codes had been identified per Saldana. (103), the thematic aspect of the analysis (3) could begin to take place through the searching for themes derived from the initial code. Subsequent to this the themes were reviewed and grouped together (4) logically based on the centre of the topic discussed. Finally, the themes were presented as a section under the results heading (5).

In line with Sparks (104) view that the reader should be given the opportunity to interpret the data in a manner suited to them, these themes, used in conjunction with direct transcript textual quotations formed the basis of the results section. Additional quotations were added to highlight viewpoints in the discussion section too. Furthermore, the quotes were able to 'speak for themselves' in representing the expert panel's opinion of content to be included in a workload monitoring tool.

5.3 Results

Within the semi structured interviews all participants were given the chance to discuss their opinions on a range of topics relating to golfing load. Below is a summation of themes and opinions expressed in the interviews by the participants relating to the subject of golfing load. These results are presented in topical themes and reflect similar viewpoints highlighted by practitioners within the specific areas discussed.

Themes for golf volume:

-The recording of Golf volume performed by an individual should be included within a golf load monitoring tool.

-Specific club categorising should be employed when measuring golf load with drivers and woods being separated from high and low irons, additionally, short game irons may also be categorised separately.

-When recording golfing load, total balls hit was considered to be the optimal method of data gathering.

-For the recording of short game measurements and putting in particular, the time taken and shots struck could be coupled to create a "shots per minute" calculation.

-Practitioners who reported a practice-based evidence approach linking golf load and injury stated that knowing if a golfer is performing a swing change is often linked to a spike in golfing load at an acute level.

Themes relating to golfer strength and conditioning:

- Overall, it was established that the recording of Strength and Conditioning sessions is essential for the purpose of recording golf volume as S&C training is "a physical stressor" on a golfer's body.

- There were some hesitancies surrounding the quantification of S&C load through a rate of perceived exertion scale (RPE) as it is a subjective measure of physical output. It was suggested the recording of "total tonnage" lifted could be used as a potential marker of a weight training load.

- Heart rate monitoring data from an external information source such as a Fitbit or smart watch could provide assistance used instead of or in conjunction with an RPE scale to help accurately track the athletes load.

Table 4

Themes for golfing load and ranking their importance

Attribute	**Sum of Rankings**	**Overall Rank**
Golf Volume	8	1
Strength and conditioning	17	2
wellness	27	3
Injury	29	4
Environmental factors	38	5

Themes for sleep and wellness

- Practitioners acknowledged the importance of sleep quality and quantity as a factor of a Golfer's load, sleep is perceived to be a key aspect of stress on a golfer's body.

- It would be important to be made aware of the number of time zones travelled through on a weekly basis as a potential indicator of a golfer's readiness to perform.

- A combination of perceived sleep quality and total sleep time was suggested as a way to quantify sleep. In addition to this, players and practitioners alike suggested the coupling of data from a smart watch or biometric device as was the case with strength and conditioning sessions.

-Sleep tended to be categorised under the branch of an athlete's overall wellness and was seen to be a key component of their overall wellness.

-Wellness ranked as the third most important topic to be included within a load monitoring tool and the majority of interviewees stated that an athletes perceived physical and mental readiness to perform influenced how they would go about the undertaking of a session with an athlete.

Themes for injury in golf

- For information within a golf load monitoring tool an initial question of "are you injured, yes or no?" may suffice initially. From there, additional questions related to the injured athlete could be asked if applicable.

- The mechanism of injury may not be necessary to be established within a load monitoring tool as subjective examination and assessment from the relevant practitioner could determine this.

- An athlete's previous injury history log was deemed important across a range of specialists as it would provide professionals with potentially relevant information to the present day.

Themes for tool completion time and adherence

- "buy in" to a golf load monitoring tool could vary immensely from player to player due to a number of external factors. Consistent completion of data input in such a tool is not expected to be universal across all athletes.

- There may be some difficulty in incorporating golf load monitoring into a golfers daily routine as it is not something that is commonly done currently. This is due to a potential viewpoint of "I haven't monitored my load so far, why should I do it now?"

- An initial guidance completion time for a golf load monitoring tool was agreed upon, universally, to not exceed ten minutes daily for the participant.

5.4 Discussion

The literature surrounding golf load monitoring has previously been proven to be limited in its depth. Williams *et al.* (27) had begun to address the lack of content and formed potential inclusion topics for a golf load monitoring tool, based off the opinions of golf coaches and sports scientists, similarly to the current study, however they then ran a pilot test to further assess. This study, conversely, encompassed a broader variety of golf specific practitioners, all of whom worked at an international level within the game to discuss specific potential content of a golf load monitoring tool. The current study dew upon their experience within professional golf and working with elite level athletes within the game. The above results highlight some form of similar perceptions shared and the reasoning for specific additions to a future golfing load tool from the perspective of players and practitioners alike. This, in essence, provides an insight into the make-up of a tool to be created in a user-friendly way and specifically created from a content standpoint by those who will use it.

The topic of golf and golf volume vastly underpins the drive behind a need for a golf workload tool. As previously stated, it is acknowledged that world class golfers have little to no idea about their weekly working volumes in terms of golf balls hit. One of the interviewees summarised that:

'when players come to me and I ask them how many balls they've hit, the general answer is "I haven't got a clue", how many balls do you normally hit? They give me the same answer.'

Given this, perhaps the primary reasoning behind creating a golf specific workload monitoring tool should be to inform players and practitioners alike of the raw number of balls hit over a period of time by a golfer. Prior to discussing any of the additional benefits that could come from the use of such a tool, the logging of balls hit fundamentally would provide additional key information surrounding a golfer's load that is, up to this point, not accessible to golfers at any level. In contrast, this is merely one aspect of golf volume and whilst it is apparent to many of the practitioner's interviewed that the number of balls hit plays a part in golf overuse injuries, it is not the isolated cause of them and additional content within a tool could create a more thorough picture regarding the issue of golfing load.

Surrounding the topic of golf volume, it was agreed by a number of interviewees that the grouping of clubs was a good idea owing to the fact that there are differing forces in a golf swing depending on the club selection, owing to clubhead kinematics and ground reaction forces. (105) Although it was not universally agreed regarding a specific breakdown, grouping drivers and woods, high irons and low irons seemed to be a potential start point for this. Besides this, shot type such as full swing or half swing was suggested as a possible sub section surrounding golf volume in a tool as it was stated by one interviewee that high volume full swings have a significantly increased stress on the tissues of the body as opposed to half swings, thus again highlighting that simply the number of balls hit could be slightly arbitrary when a golfer is recording their golf load.

Despite the acknowledgement that balls hit may not be the only segment of golf volume, a number of the interviewees highlighted a range of benefits of its inclusion. Firstly, the majority of those asked stated that it was the most basic and key data to be recorded to try to ensure maximum adherence to the tool as well as keeping the time required to complete the tool to a minimum. From there, a weekly number of balls hit over time would evolve into there being enough information recorded to comprise individual weekly averages and therefore enable a practitioner and player to notice spikes in workload both acutely and over a longer period of time.

“With averages, we can look at a player’s consistency of volume, and I think that is a good thing,” stated one participant, “and this is pertinent if you have a golfer who is consistently hitting 500 balls a day for years who will be much more tolerant to that load than someone who suddenly starts hitting 500 balls a day but is used to only hitting 200.”

This summation of practice based evidence ties in with the fundamental principles underpinned in the acute:chronic workload research carried out by Hulin, Gabbett and others. (8,34,37) As these principles of gradually increasing load chronically and incrementally would appear to be applicable to golfers, practitioners and players equally should pay attention to an increase in acute volumes as a potential injury precursor. In golf, these acute loads may come in the form of increased balls hit per week and the parameters of such changes could be more drastic and give an even greater injury risk as load is not monitored at all so there is no recording of how much a golfer’s acute workload has increased compared to the last week. One cause of this, multiple interviewees stated, is when a player is working on technical swing changes and so within a potential workload monitoring tool it could be advised to include a question simply asking if a player is going through swing changes this week would add information supporting the data surrounding golfing load. Furthermore, this may act as a reinforcing reminder to a player and their support system that swing changes often mean an increased amount of balls hit and therefore are a pre cursor to potential injury likelihood being higher.

The final topic surrounding golf load and the possible ways to measure it centred around the short game and putting in particular. As with balls hit, the number of putts struck per week or the time taken dedicated to putting is unknown by many players. This is partly theorised due to the difficulty in keeping track with every putt struck but also a lack of attempts to do it in most cases. Where the difference lies between the recording of long and short game strokes is in the perceived approach to recording short game golf volume. A theme that was discussed and conceded was the notion of a putts per minute calculation. This would be done by taking the putts attempted within a short game session and recording the length of that session to create this figure. This was reasoned due to the short game taking much more time and consideration prior to performing the shot than a drive or long iron shot, so there would be less balls struck over a longer period of time. In addition to this, it is known that golfers tend to stand in a semi flexed position when putting and often do not rise from this position until they have completed their ‘set’ of putts attempted. This set up places additional strains upon the body that could contribute to golfers experiencing lower back pain. As such, a strokes per minute valuation may give players and practitioners alike the time spent in a semi flexed position which could be a potential injury risk surrounding the lumbar spine as it is known that this area is frequently injured amongst golfers. (12,47)

Strength and conditioning sessions amongst golfers are commonplace at an elite level, as with other sports, this form of training is an integral part of optimal athletic preparation. (106) Both interviewees that were PGA European tour level players stated that they carry out S&C sessions on a weekly basis as well as the majority of their peers doing the same. Across all interviewees, the inclusion of a section recording strength and conditioning data was ranked as the second most important data to capture, following golfing load, when looking at a potential load monitoring tool, (see table 4). As various authors state, (33,34) gym session numbers and ‘work done’ coupled with sport specific training are combined to give an athletes total external load, therefore the inclusion of both aspects of load were seen to be of paramount importance across all participants of the interviews. Whilst it was comprehensively agreed that the data of a strength and conditioning session should be included within a golfers’ load over a specific time period, there were several alternative viewpoints put forth as to how this could be done.

A range of the professional’s, including player’s, saw a combination of time taken to do a session multiplied by RPE of that session as an adequate unit for S&C load. This is a method echoed within some relevant academic literature and carried out as a way of quantifying training load. (107,108) This approach could allow for favourable data inputting however there it was highlighted that the subjective aspect of an RPE may prove inaccurate and over time could affect an acute:chronic ratio for physical training load of an athlete. Conversely, total tonnage (total mass lifted in Kilograms) of a session could be used as a direct measure of a golfers S&C load. This method would be objective and accurate however could be time consuming and would possibly need open access to a load monitoring tool for the athlete to record the data as they complete the session rather than retrospectively, as is the case with a session's RPE. The method of total tonnage could potentially be integrated with the use of an external application to the tool. One interviewee gave the following thoughts surrounding the topic:

"*total tonnage or total weight lifted could be very useful if they're tracking their workouts with total number of reps and sets involved as well. I already use a tracking tool called push band and that also takes the work done in terms of wattage as well.*"

In addition to this, a combination of subjective and objective measurements may provide professionals and athletes with more information than either one isolated. (109) Whilst additional information may be useful a potential golf load monitoring tool must be user friendly and time efficient to have the best chance of data completion and adherence from the athlete so the selection of how much content to include is fundamental to such success. With this in mind, challenges could arise between including enough information to have a positive impact in a golf specific load monitoring tool and including too many themes to gather data and this could inadvertently cause a decrease in data input due to the time taken to complete the tool. It was specified by several interviewees that an initial tool containing only the most vital components of golfing load could be included in a tool, perhaps just the shots struck on a weekly basis and the acknowledgement of strength and conditioning sessions completed. Given the fact that currently even these aspects are not recorded, any information gathered that could help to report total golfing load would be a positive step in the right direction and there may be some resistance to this process being integrated into a golfer's habits so perhaps it would be prudent not to overload them with too much to do to give the highest chance of a golfer adhering to a golf load monitoring tool.

The results of the semi structured interviews surrounding the theme of the importance of sleep and wellness as a broader topic followed a similar pattern to those relating to strength and conditioning but applied to golf load volume. It was widely accepted that sleep, travel and overall wellness were interconnected and formed a part of the internal load of the athlete in question. Furthermore, it was also conceded the importance of the 'Wellness' of an athlete when looking at the broader depiction of that person. This grouping by the interviewee's was not something foreseen by the researcher and hence did not command too much attention within literature searches when looking at training load monitoring. As with a number of other aspects of golfing load, objective and subjective measurements to track sleep and or wellness were put forward by some of the interviewees.

Zambotti *et al.* (110) measured sleep and cardiac function of a Fitbit charge which showed good agreement with polysomnography and electrocardiography devices thus supporting its use in assessing such measures. However, the authors did note that the subjects were of an adolescent population and further validation would be required to assess the reliability of a Fitbit device over prolonged periods of time. Therefore, if such data is available to athlete and their support network alike, the use of objective data may be encouraged as it has at least been proven somewhat accurate through the study of Zambotti *et al.* (110) Looking at sleep data or asking perceived sleep quality coupled with the overall feeling and wellness of an athlete is an important procedure within their daily routine. The majority of interviewees stated that this was something that already took place and they used as a marker and as a potential indicator for a drop in energy level, readiness to perform or performance itself, be that golf or in the gym. It was also inferred that training may be subject to change if perceived wellness was reportedly lower than usual and that could occur with compensation in training volume and or training intensity.

Discussions surrounding the topic of time zones travelled and their importance produced different answers amongst interviewees. It was agreed that time zones travelled, particularly five or more hours in net change would impact a golfer. This is supported by Lee & Galvez as well as Leatherwood & Dragoo (111,112) where travelling west, the rate of adjustment to time zone is equal to one day per time zone travelled. Subsequently, this produces its own practical challenges to a high-level golfer, who may be travelling multiple time zones in consecutive weeks, due to the demanding nature that is a professional golfer's schedule. Tournaments can be based on different continents from week to week and the fact that the turnaround from one tournament to another is only Sunday to Wednesday, (tournament play being Thursday to Sunday) there is very little time to adjust to a new time zone or catch up on sleep missed due to changing time zones.

Additionally, cognitive and some physical measurements were adversely affected by jet lag and a circadian disruption. Despite this, it was the view of one player interviewed that they didn't correlate travel as being overly important when measuring golfing load. The majority of other interviewees from a practitioner's stand point saw that the questioning of time zones travelled that week would heed a warning to a player of the commonality of illness and increased injury risk from travel and therefore could provide a valuable reinforcement of such risks within the context of golfing load. As table one suggests though, under the heading of environmental factors, the inclusion of time zones travelled was seen to be far less important than other topics if creating a golfing load monitoring tool. This can be partly attributed to the fact that there aren't golfing performance indicators derived from this topic, merely the information from time zones travelled could be used as an indicator of potential risk of injury.

A great amount of time was devoted to the discussion surrounding the theme of injury amongst all golfing professionals alike. At the heart of the research piece is a known fact that golfers suffer training load errors. (9,12,21) With proven steps taken by other sports to monitor workload with the goal of reducing injury and therefore time away from competing and or practicing, the challenge is for this methodology to be inputted into the game of golf. Before this can occur it must be quantified what the workload is of elite golfers is, and therefore obtain a baseline dataset before any implementation of such work occurs.

When conducting talks with the interviewees regarding the matter of injury it was reported back universally that a section on injury should be included within a golf load monitoring tool. This was attributed to the fact that it is of the upmost importance for player and practitioner alike to know at all times if the athlete is injured as an injury could fundamentally affect the work carried out by the athlete over a prolonged period of time. Given the importance of creating a tool that is going to be adhered to, the first and most important question within an injury section of a tool was deemed to be simply asking the athlete if they were injured or not. From this there would then be a set of extension questions if the answer was yes and the athlete could be prompted onto another section of the load monitoring tool if the answer was no.

Dialogues then moved to the importance of injury sub sections such as the mechanism of injury, current treatment of an injury and injury duration. It was noted that some interviewees deemed number of practice or competition days lost due to injury as an important statistic, therefore, in a potential tool one feature of an injury subsection could be a tracker of days and specific dates lost around a particular injury. Some medical professionals amongst the interviewees advised that diagnostic aspects of an injury and mechanism for injury could potentially be left out of any questioning within a tool. The consensus surrounding this was that a medical professional should be contacted if an athlete is injured and speculation surrounding an injury and the subjective nature of a perceived injury would not be of benefit to anyone within an athlete’s support group. When further questioned on this, however, it should be mentioned, that if an injury has been properly diagnosed then the nature of an injury could be included within a ‘notes’ section of a golf load monitoring tool.

Despite injury avoidance being a primary concern to a golfer, thus enabling them to practice and compete pain free, collectively recording an injury in a golf load monitoring tool was seen to be of a lesser importance across all interviewees. It ranked fourth (see table 4.) in the order of importance within a potential tool and this can be attributed to the fact that the outlying opinion across professionals was that deriving a golfer’s load is of the upmost importance initially. Stemming from this injury prediction and therefore reduction may become a secondary outcome of a workload monitoring tool, as shown by the work of Windt, Gabbett and others. (8,97)

The final subject within the topic of injury discussed was some practitioners alluded to the importance of an athlete’s previous injury history and the benefits that having such information to hand may bring. It was suggested that this could be collected via a dropdown or notes section within the injury topic of a load monitoring tool. That way it would be left up to the individual to record as much or little material surrounding an injury as they deem appropriate thus not taking up any unwanted time in the process. This would also serve as an injury chronology as a tool develops and could be branched out into recording subsequent valuable data such as practice and tournament days lost and may highlight injuries at particular time points that could be attributed to specifics within the tool. That said, the initial objective as with other aspects of a workload monitoring tool should be to record the key elements within a section to set a foundational simple tool that is easy to understand and adhere to.

To conclude discussions surrounding a golf specific load monitoring tool, all interviewee’s were asked their opinion on the potential time it would take to complete an initial tool, once conceptualised. It was unanimously agreed that an appropriate time frame for an athlete to complete daily load monitoring information would not exceed ten minutes for start to finish. This is an important marker for pilot load monitoring tools in the future as adherence and completion of data is a potential issue that practitioners will face. Expanding upon this, a mixture of practitioners and golfers alike stated that the time an athlete would be willing to spend on recording their daily loads would vary hugely amongst individuals and could depend on an athlete's attitude towards sport science and their interest in relevant but non golf specific activities within their schedule. It was also noted that acceptance and implementation of daily load monitoring into a golfer's routine may not be adopted without friction immediately, if at all. All interviewees were of the belief that correct education on the importance of load for a golfer and stressing the benefits of its inclusion in a routine would likely yield the best results. Furthermore, if load monitoring could be adopted by junior golfer's early into their career then it would be normal once they turn professional. In this instance, further research into adolescent populations would be required in a golfing context however the work of Murray, (113) and Hartwig *et al.* (114) outlines some of the load principles and findings within youth athlete populations.

5.5 Summary of chapter findings

To summarise, activity relating to golf performance was deemed to be the most important inclusion topic for a LM tool. Within that subsection, grouping clubs when recording shots taken was suggested to identify time spent on the long and short game. If a subsection is to be included surrounding injury, asking the golfer if they are currently injured with a yes/no answer may initially suffice. Adherence to a golf load monitoring tool may range amongst individual players, with a short daily completion time being optimal for consistent data input.

5.6 Chapter conclusions

In conclusion, many complexities and an array of opinions were expressed amongst all interviewees on the various topics discussed relating to golfing load. The purpose of these discussions was to come to an agreement upon the importance of specific topics for a golf load monitoring tool upon such a tools conception. The ranking of such topics highlighted which areas were seen by golfing practitioners as absolutely essential in a potential tool and those aspects of a golfer’s routine that were important to them but perhaps less so in a load monitoring tool. Golfing load ranked as the most important area to include and the interviewee’s suggested an outline of individual aspects including club groupings, total balls hit and a strokes per minute quantification for putting loads. Wellness was also seen to be important to golfer’s and practitioners alike, thus mirroring the principles surrounding internal and external load and non-golf performance related stressors to an athlete such as their perceived wellness and or fatigue levels linked to sleep or travel, highlighted by Hulin, Gabbett *et al.* (8,64,65)

Chapter 6

Conclusions

6.1 General conclusions

Concluding the research piece in its entirety, it can be stated that there is an obvious lack of research surrounding the subject of golf load monitoring and therefore more research on the topic must be undertaken to recognise the sport specific nuances of athlete load monitoring. It is also clear through the literature review of injury in golf that training load errors are exceedingly common amongst professional golfer's with increased time spent practising and playing likely to be causal to this. (4,9) This reinforces the need for further load monitoring research given the portion of overuse injuries in Golf. Having researched athlete load monitoring across a multitude of sports, the principles of the acute chronic workload ratio can be applied to golf, (8,37,65) as well as other aspects of load monitoring that could be modified to meet the sport specific demands. Training load monitoring has been seen to be successfully applied to other sports within the academic literature and it is important that further research is undertaken within the game of golf.

It became clear throughout the literature reviews conducted, that there was a noticeable lack of Golf load monitoring being carried out. Given the link of training loads and injury in other sports coupled with the lack of golf specific load monitoring literature, this lead to the current qualitative research piece to establish the possible content of a golf load monitoring tool via the opinions of an expert panel of various golf discipline's, with semi structured interviews being the method of carrying this out.

It was important to find a consensus of which aspects of golf should feature within a golf load monitoring tool and golf volume ranked as the most important inclusion topic followed by an athlete's strength and conditioning work. As seen in the prior research of load monitoring, practitioners and golfers alike recognised the importance of 'overall load' and the sum total of internal and external loads by concluding that wellness should be included within a golf load monitoring tool. Objective measures, if proven to be accurate, may be better than subjective but an athlete will likely be able to feedback their perceived readiness to train and answer questions regarding mood, sleep quality and fatigue based off their feelings. It is reasonable to determine that if creating a workload monitoring tool, recording golf load, physical training (S&C) load and readiness to perform may be a good platform to begin with to capture the fundamentally important data relating to total load of a golfer. Whilst travel, nutrition and some environmental factors could be attributed to potential injury or illness pre cursors to a golfer, the aforementioned subjects were perceived to be important to specific golfing load, and are therefore a logical place to begin with the inception of a golf workload monitoring tool.

6.2 Limitations

This research piece had a number of limitations that could be addressed by researchers in the future:

- In the golf specific injury literature review, throughout the study's there was a general theme of injury incidence, however causality of injury was difficult to establish.
- A portion of the research on injury in golf mixes studies looking at amateur and professional golfers so specific findings attributed to high level golfers were difficult to establish in some cases.
- Within the literature review for training load monitoring, the researcher may have overlooked the importance of wellness to training load as well as the commonality of travel and the effect of time zones on performance. As wellness ranked third in importance for inclusion within a golf specific load monitoring tool, perhaps a greater understanding of the current literature surrounding this topic could have been achieved prior to the semi structured interviews taking place.
- The intended number of semi structured interviewee's was ten, however the total number of people interviewed in the current study was eight, due to not being able to

find two experts that met the inclusion criteria and were willing to participate. This could have provided additional insight from the perspective of another golf coach and doctor to compare their opinion to another expert within their field of work.

- This study was the first instance of qualitative research being undertaken by the researcher. Given the difficulty in interpreting qualitative data, it may have been that a more experienced researcher would have arrived at different conclusions than those summarised in the results section for the current research piece.

6.3 Areas for further research

This current study was carried out owing to a lack of literature surrounding the subject of training load monitoring in golf. Only one previous study relating to this particular topic had been found, the work of Williams *et al* (27). Within the methodology of this research piece there was a set of parameters given to an expert panel to be included in a pilot GLMT study, which was then subsequently implemented. This piece of work aimed to use a panel of experts to identify specific potential inclusion topics and create rigour as well as validity to these and perhaps overlooked by Williams *et al.*

Should this research piece have employed a full Delphi method, following on from the data analysis of the semi structured interviews, a first attempt of a golf specific load monitoring tool would have been sent out to the experts in questionnaire form based off the results of the semi structured interview. As this was not the case, the current study terminated following the data analysis of the interviews. Whilst this piece of research has answered some of the research questions posed and identified load monitoring principles adopted by other sports, it is merely a foundational base for further research to be carried out.

Whilst ideally maintaining a high proficiency of skill and experience within the expert panel, an initial tool could be created with the duration designed to not exceed the guidance of ten minutes for pilot testing amongst golfers. This would then run for a period of time, ideally 12-

24 weeks to allow for sufficient data collection to enable the quantification of acute and chronic golf loads, as per other sports such as rugby, cricket and AFL football. (22,37,62)

The ideal endpoint of a golf load monitoring tool would be a platform that is user friendly, easy to comply with and has the capabilities of extracting from the data collected to provide the athlete with weekly and monthly reports that could provide information to help improve performance whilst still serving primarily as a tool to monitor and lower injury risk. Whilst this may take years or even decades to become a reality, with the correct research and harnessing of technology this may be an attainable goal for the game of golf. Given the success that other sports have had with load monitoring, it is time for such a global sport to catch up with the modern trend of applied sports science.

6.4 Potential training load monitoring tool for golf

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
competition	holes	holes	holes	holes	holes	holes	holes
golf course holes (excluding competitions)	holes hours	holes hours	holes hours	holes hours	holes hours	holes hours	holes hours
driving range Wood / High Irons	balls hit hours	balls hit hours	balls hit hours	balls hit hours	balls hit hours	balls hit hours	balls hit hours
Driving range low irons	Balls hit hours	Balls hit hours	Balls hit hours	Balls hit hours	Balls hit hours	Balls hit hours	Balls hit hours
putting / short game	Putts attempted hours	Putts attempted hours	Putts attempted hours	Putts attempted hours	Putts attempted hours	Putts attempted hours	Putts attempted hours
fitness training for golf	hours	hours	hours	hours	hours	hours	hours
other training incl. warm-up	Session RPE hours	Session RPE hours	Session RPE hours	Session RPE hours	Session RPE hours	Session RPE hours	Session RPE hours

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