Cardiff School of Sport

DISSERTATION ASSESSMENT PROFORMA:

Empirical [1]

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Dissertation title:	Does Balance Training Have an Effect on Agility in Tennis?		
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Comments	Section
	Title and Abstract Title to include: A concise indication of the research question/problem. Abstract to include: A concise summary of the empirical study undertaken.
	Introduction and literature review To include: outline of context (theoretical/conceptual/applied) for the question; analysis of findings of previous related research including gaps in the literature and relevant contributions; logical flow to, and clear presentation of the research problem/ question; an indication of any research expectations, (i.e., hypotheses if applicable).
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CARDIFF METROPOLITAN UNIVERSITY
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CARDIFF SCHOOL OF SPORT

DEGREE OF BACHELOR OF SCIENCE (HONOURS)

SPORT CONDITIONING, REHABILITATION AND MASSAGE

DOES BALANCE TRAINING HAVE AN EFFECT ON AGILITY IN TENNIS?

(Dissertation submitted under the discipline of SCRAM)

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DOES BALANCE TRAINING HAVE AN EFFECT ON AGILITY IN TENNIS?

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ABSTRACT

Context: Balance and agility are important fitness components in tennis, but there is little research into whether balance training can improve agility. Investigating whether balance training can help to improve agility could help to reduce injury rates, as agility is one of the inherent demands of tennis that causes micro-trauma injuries. ***Objective:*** To determine any performance enhancement in agility after participation in a six week balance training programme in university male tennis players. ***Setting:*** All pre and post testing took place in Cardiff Metropolitan Tennis Centre and balance sessions took place in the National Indoor Athletic centre (NIAC) at Cardiff Metropolitan University. ***Participants:*** 16 male Cardiff Metropolitan tennis players aged 18-25 were assigned to an experimental (n = 8) or control (n = 8) group. Players were excluded if they had sustained a lower limb injury in the preceding 12 months. ***Intervention:*** The experimental group took part in a six week training programme that included various balance exercises and progressions. ***Baseline Measure:*** Data was collected using the agility t-test before and after the six week intervention period for both experimental and control groups. ***Results:*** The current study found no significant improvements in agility performance within the experimental group from pre to post tests when compared to the control group ($P > 0.05$). However there was a trend towards improvements in agility after the six weeks of balance training, in both groups, but a larger improvement in the experimental group. ***Conclusion:*** This study suggests that balance programmes may be an effective means of improving agility, which in turn may be helpful in preventing injuries. More research is needed in this area to confirm these findings.

CHAPTER ONE

INTRODUCTION

1.0 Introduction

Sport is one of the most widespread leisure activities of European citizens and is an important social and economic phenomenon. (Kisser & Bauer, 2012, online). Athletes involved in sport are always striving for excellence and in doing this put themselves at risk of injury; it is therefore important to look at ways in which injury can be prevented. The game of tennis is extensively studied and scrutinised by sport scientists and medical physicians, so that information can be provided in order to reach and maintain the optimal level of physical fitness (International Tennis Federation, 2004, online). Sports medicine plays a vital role in the growth and development of new diagnostic, treatment, injury prevention and rehabilitation procedures and the continued health of tennis players of all ages and levels of play (International Tennis Federation, 2004, online). Dr Babette Pluim, member of the International Tennis Federation Sports Medical Commission, has compiled several guidelines for injury prevention in tennis. (International Tennis Federation, 2004, online). The guidelines look at common tennis injuries such as calf muscle strain ('tennis leg') and ankle sprain and how to treat the injuries and to prevent re-injury. These guidelines are specific to tennis, but only look at preventing re-injury and it would be more beneficial to prevent injuries from the start. One organisation that has looked at preventing injuries, rather than preventing re-injury is the Fédération Internationale de Football Association (FIFA). The FIFA Medical Assessment and Research Centre developed an injury prevention programme called 'The 11' which was aimed at reducing injuries among male and female amateur football players (Rahnama, 2012). Injury prevention programmes are consistently having to be developed and changed, and so a new programme was established named 'The 11+', which has been reported to significantly lower the risk of injuries overall, overuse injuries and severe injuries (Rahnama, 2012). Any preventative action needs knowledge about frequency, severity and circumstances of the injuries sustained in the sport (Kisser & Bauer, 2012, online).

It is important to be able to reduce the amount of injuries in sport as sport accounts for a significant proportion of all injuries. It is estimated that 14% of all medically treated injuries are related to sport (Kisser & Bauer, 2012, online). The collective term used to define sports injuries is: 'injuries that require any treatment from a team physician or loss-of-time from competition or training' (Brooks & Fuller, 2006, p.462). The demands of tennis on the player's body can affect the upper and lower extremities as well as the trunk and can lead to characteristic injury patterns (Ellenbecker, Pluim, Vivier & Sniteman, 2009). In tennis, the lower extremity is the most frequently injured region (range 39-65%), followed by the upper extremity (range 24-46%) and the most frequently injured parts of the lower body are the lower leg, ankle and thigh, with the ankle sprain and thigh muscle strain the most common. (Ellenbecker *et al.,* 2009). Renstrom (2002) states that the major type of injury in tennis players is due to microtrauma repetitive overload, which can be due to intrinsic or extrinsic factors of tennis and the inherent demands of the sport such as biomechanical and metabolic requirements.

Tennis is a highly demanding sport and to be competitive and successful, tennis athletes will need a mixture of speed, agility and power combined with medium to high aerobic capabilities. (Fernandez-Fernandez, Sanz-Rivas & Mendez-Villanueva, 2009). Tennis demands a complex interaction of physical components and successful performance cannot be defined by one predominating physical attribute (Fernandez- Fernandez *et al.,* 2009). Motor skills such as power, strength, agility, speed, and explosiveness, as well as mental strength, and a highly developed neuromuscular coordinating ability can help a tennis athlete perform at a higher level (Fernandez- Fernandez *et al.,* 2009).

Agility is one of the more important components of tennis and can be defined as 'the skills and abilities needed to explosively change movement velocities or modes' (Baechle & Earle, 2008, p.458) or 'is the capacity to control the direction of the body or body part during rapid movements' (Norris, 2011, p.105). If a tennis player has good agility, the player will have the best all-round court skills possible with the greatest speed and control and the least amount of wasted energy and movement (Pearson, 2006). Agility can also help to prevent injuries and teach the muscles how to fire properly and control minute shifts in ankle, knee, hip, back, shoulder and neck joints for optimum body alignment (Pearson, 2006). Another important factor in reducing injuries and having optimum body alignment is balance. Balance 'is the ability to maintain equilibrium by keeping the line of gravity of the body within the body's base of support' (Norris, 2011, p.105). By having high levels of balance and coordination, tennis players will be able to move faster and change direction more quickly, whilst maintaining control (Twist & Benicky, 1996). Being able to maintain control, whilst performing tennis movements, can be an important factor in reducing the risk of injury. Balance can also be key to good agility, because if a tennis player is able to keep the centre of gravity between their feet, they will be better balanced and ready to shift direction as quickly as possible.

In considering the aforementioned, it is evident that both agility and balance are both important in tennis but there is little research into how the two can be linked together through training methods. Studies have been done investigating how balance can help to improve other components of fitness, for example a study carried out by Yaggie and Campbell (2006) concluded that a four week balance training programme was an effective means of improving joint proprioception. There are also studies demonstrating how agility can be improved by using different training methods, for example plyometric training. Asadi (2012) concluded that six weeks of depth jump training and countermovement training improved Illinois agility test times and T-test times. Being able to link balance training and agility could help improve two important components of tennis in one training session and in addition, if agility could be improved, it could reduce the risk of injury. Consequently this study will propose to identify if participation in a six week balance training programme will cause a significant difference in agility performance within male tennis players.

CHAPTER TWO

REVIEW OF LITERATURE

2.0 Review of Literature

2.1 Balance

Balance is the process of maintaining the position of the body's centre of gravity vertically over the base of support (Hrysomallis, 2011) and can be broken down into two different categories, static balance and dynamic balance. Static balance is the ability to maintain a base of support with minimal movement (Winter, Patla & Frank, 1990). Dynamic balance may be considered as the ability to perform a task while maintaining or regaining a stable position or the ability to maintain or regain balance on an unstable surface with minimal extraneous motion (Paillard & Noe, 2006).

The ability to maintain balance 'relies on rapid, continuous feedback from visual, vestibular and somatosensory structures' (Hrysomallis, 2011, p.222). Somatosensory input 'provides information concerning the orientation of body parts to one another and to the support surface' (Lephart & Fu, 2000, p.38). The vision system, also known as the oculomotor system, measures the orientation of the eyes and head in relation to surrounding objects and the vestibular system supplies information that measures angular, linear and gravitational accelerations of the head in relation to inertial space (Lephart & Fu, 2000). If an injury occurs, the nerve pathways within these systems can become damaged, causing impairment in the transmission of nerve impulses (Brukner *et al.,* 2012). This can lead to decreased balance and coordination and an increased risk of injury or re-injury.

Non-contact mechanisms, such as landing from a jump, frequently lead to joint or ligament injuries that are probably the result of strength deficits or impaired stability and balance (Wikstrom, Powers & Tillman, 2004). Balance can be improved by repetitive training experiences that influence motor responses (Balter, Stokroos, Akkermans & Kingma, 2004) or by training experiences that influence a person's ability to attend to relevant proprioceptive and visual cues (Ashton-Miller, Wojtys, Huston & Fry-Welch, 2001). By partaking in balance training it is hoped that an athletes balance will improve and therefore reduce the likelihood of injury.

2.2 Agility

Agility is 'a rapid whole-body movement with change of velocity or direction in response to a stimulus' (Sheppard & Young, 2006, p.919). It 'permits an athlete to react to a stimulus, start quickly and efficiently, move in the correct direction or stop quickly to make a play in a fast, smooth, efficient and repeatable manner' (Verstegen & Marcello, 2001, p.140). The multifactorial nature of agility can also be represented by a deterministic model, indicating the various factors contributing to performance (Figure1).

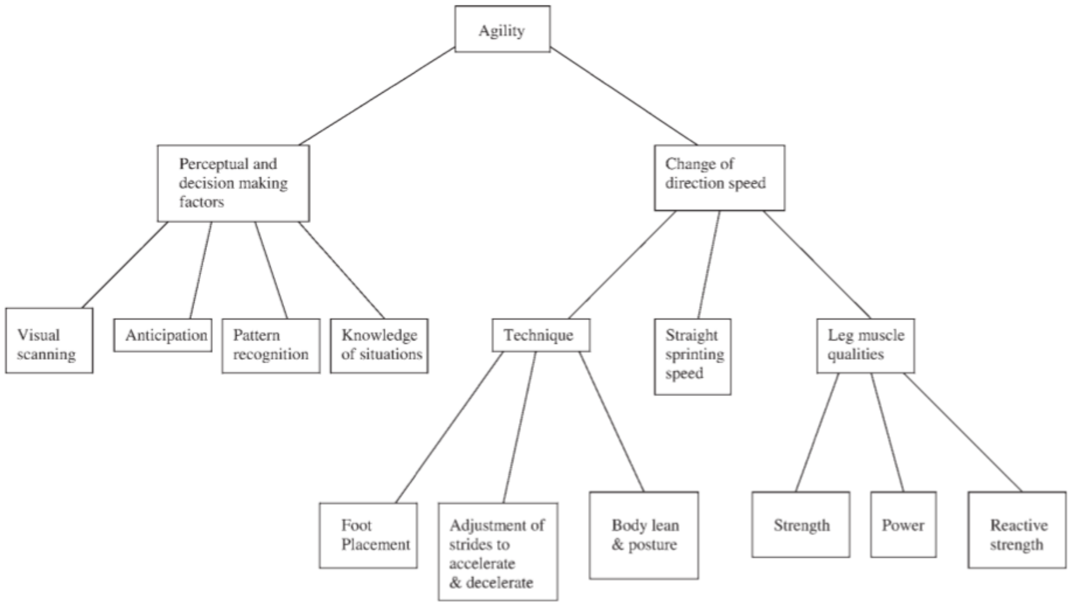

Figure 1: Deterministic model of agility performance (Young, Hawken and McDonald, 1996).

The development of agility is often the responsibility of the strength and conditioning coach. Agility has relationships with trainable physical qualities such as strength, power and technique, as well as cognitive components such as visual-scanning techniques, visual scanning speed and anticipation (Sheppard & Young, 2006). Identifying the importance of these relationships with trainable physical qualities may assist coaches in developing training strategies to maximise the development of agility and reducing injury rates (Farrow & Young, 2006). Finally agility training is thought to be able to enhance motor programming through neuromuscular conditioning and neural adaptations of joint proprioceptors, golgitendon organs and muscle spindles. Therefore agility should improve when balance and control of body positions during movement is enhanced. (Miller, Herniman, Ricard, Cheatham & Michael, 2006).

2.3 Tennis

'The game of tennis can be best described as a multi-directional, explosive, stop-start activity with players maintaining dynamic balance and control so they can effectively hit the ball' (Pearson, 2006, p.34). Players are required to change direction, decelerate, stop instantly and start again, jump into the air, land and instantly move off in another direction, all the time maintaining balance and control to hit the ball with efficient and effective balance (Pearson, 2006). During a competitive match, it is common for players to have more than 1,000 direction changes (Kovasc, 2009) and to be required to coordinate lower body, upper body and racquet movement in different planes of motion (Elliot, Reid & Crespo, 2003).

Balance is a very important component in the game of tennis. By having high levels of balance and coordination, tennis players will be able to move fast and change direction more quickly, whilst maintaining control (Twist & Benicky, 1996). Being able to maintain control, whilst performing tennis movements, can be an important factor in reducing the risk of injury. Also, balance does not work in isolation and poor balance leads to poor technical skill and skill development. Balance can be thought of as the single most important component of athletic ability because it underlies all movement (Gambetta, 1996).

During a point in a match, tennis players can make just a single movement or more than 15 directional changes during a very long period (Kovasc, 2009); that is why agility is such an important factor. Agility deals with the changes in direction and the ability to effectively couple eccentric and concentric actions in ballistic movements (Miller, Hilbert & Brown, 2001). If the player were not able to deal with these changes in direction and effectively couple eccentric and concentric actions, they would be more prone to injury whilst playing tennis.

2.4 Sport Injury Rates and Mechanisms

Like many other sports, playing tennis at any level places participants at risk of injury and many injuries that occur in tennis are also common to other sports (Pluim, Staal, Windler & Jayanthi, 2006). When looking at injury rates in tennis it is clear that ankle sprains, low back pain and knee injuries are some of the most common injuries that occur (Hjelm, Werner & Renstrom, 2010). 31-67% of injuries occur in the lower extremities, followed by 20-49% in the upper extremities and 3-21% in the trunk (Hjelm *et al.,* 2010). Furthermore, most injuries that occur in tennis are acute injuries rather than chronic injuries and the most common acute injury is the ankle sprain due to high twisting forces (Bylak & Hutchinson, 1998).

The most common injuries in tennis are due to microtrauma repetitive overload. Renstrom (2002) states that microtrauma injuries can occur due to the inherent demands of the sport, which include biomechanical requirements, metabolic requirements, strength and agility. Being able to improve a player's ability to cope with these demands could help to reduce his or her chance of sustaining an injury. When looking at the most prevalent injuries in tennis, it is clear that they can cost a lot of money to treat and can cause the athlete to miss time from their sport. Dutch annual sports related ankle sprains costs alone, can roughly be estimated at €187,200,000. (Verhagen, Hupperets, van Tulder & van Mechelen, 2010), and it can take six weeks to three months before ligament healing occurs (Hubbard and Hicks-Little, 2008). It was also found that in Switzerland the direct cost of lower back pain was estimated at €2.6 billion (Wieser *et al.,* 2011) and knee injuries account for a large part of the cost of medical care of sports injuries (Loes, Dahlsted & Thomee, 2010). These studies were undertaken outside the UK, but it can be hypothesised that the same injuries in the UK would have similar impacts in regards to cost. These studies are not directly linked to tennis but the injuries mentioned are some of the most common in tennis. This indicates that there could be a significant saving in treatment costs if there was successful prevention of these injuries and there could be less time lost from playing tennis.

2.5 Balance Training Studies

There are a few studies that look into the effects of balance training and what it can help to improve. Yaggie and Campbell (2006) looked at the effects of balance training on selected skills by undertaking a four week balance training programme with 36 recreationally active volunteers. Measurements of postural sway, postural limits, vertical jump height, shuttle run time and time on the BOSU balance trainer were taken before and after the four week balance training programme. It was concluded that the balance training was an effective means of improving joint proprioception, reducing shuttle run times and reducing postural sway. Knowing that balance training can improve these areas could mean that balance training could improve other areas, for example agility.

Another study looked at how balance training can help to improve function and postural control in those with chronic ankle instability (McKeon *et al.,* 2008). The study used an intervention group of six males and 10 females and a control group of six males and nine females. The intervention consisted of a four week supervised balance training programme that emphasised dynamic stabilisation in single-limb stance. The four weeks of balance training significantly improved self reported function, static postural control and dynamic postural control.

From the studies it is clear that a balance training programme can help to improve some areas like proprioception, postural sway and dynamic postural control but there is not much research on how balance training can help to improve agility, one of the main fitness components in tennis. Having recognised the need for research into whether balance training can help to improve agility, consideration is required for the duration of a programme to ensure a time effective modality is found. The two studies previously mentioned, which looked at the effects of balance training on selected skills and the effects of balance training on improving function and postural control in those with chronic ankle instability, showed that results can be seen after completing a balance training programme for just four weeks.

A recent study by Gioftsidou *et al.*, (2012) investigated the effects of balance training programmes on the prevention of injuries in soccer. The study involved two different training programmes to compare which one would deliver better results from different training frequencies. The first training programme was carried out six times a week for three weeks, and the second training programme was carried out three times a week for six weeks. ‘The results showed that both training groups improved their balance ability similarly despite the different frequency of the balance training programme’ (Gioftsidou *et al.*, 2012, p.639). This study shows that improvements in balance can be achieved in just three weeks, but that could be due to the amount of extra training that is being carried out, due to the athletes being professional football players. An improvement of this magnitude may not have been seen in only three weeks, in a different population such as recreational sportspersons.

A study carried out by Heitkamp, Horstmann, Mayer, Weller and Dickhuth (2001) looked at strength gains and muscular balance after balance training. 30 people participated in this study, of whom 15 undertook the strength-training programme and 15 undertook the balance-training programme. Both groups trained for two to three times a week for four to six weeks until 12 training units were completed. After the training programmes it was clear that the participants who carried out the strength training programme improved in balance and strength and the same wit the participants who carried out the balance-training programme. McGuine and Keene (2006) carried out a study that looked at the effects of a balance training programme on the risk of ankle sprains in high school athletes. The balance training program in this study was carried out to begin with five times a week and then was reduced to three times a week, but each session was only ten minutes long. The study concluded that a simple, inexpensive, balance training program will reduce the rate of ankle sprains by 38% in male and female high school soccer and basketball players. Finally Eils and Rosenbaum (2001) carried out a multi-station proprioceptive exercise programme in patients with ankle instability, which used similar exercises that can be found in balance training programmes. The training programme was carried out for six weeks, once a week and it led to significant improvements of proprioceptive capabilities in chronically unstable patients.

From the previous studies it is clear that balance training programmes which run from anywhere between three to six weeks can have positive results for the athlete, for example with improved strength and balance. However, the shorter the balance training programme, the more sessions were carried out each week. For instance, three weeks of balance training included six sessions a week whereas six weeks of balance training could include just one session a week. Thus, when researching the effects of balance training on agility, the balance training programme would be carried out once a week for six weeks.

2.6 Base Line Testing/ Testing Protocol

Having established the duration of the balance training programme, the base line testing measure must be determined in order to make comparisons prior to and after the training programme is completed. It is important that the testing protocol should be chosen based on the specificity of movements inherent within the sport. Looking at previous studies, it is clear that there several tests which can be used to measure and test agility. One study has previously looked at the effects of a six week plyometric training programme on agility. The subjects were divided into two groups: an experimental group and a control group, and all the subjects participated in two agility tests including the T-test and Illinois agility test both pre and post testing (Miller *et al.,* 2006). The t-test is used to determine speed with directional changes such as forward sprinting, left and right shuffling, and backpedalling (Miller *et al.,* 2006) and the Illinois agility test is used to determine the ability to accelerate, decelerate, turn in different directions, and run at different angles (Miller *et al.,* 2006). These tests were selected because of their reported validity and reproducibility (Miller *et al.,* 2006). Both of these tests showed improvements in the athlete’s agility but it is not clear how they measured the times and so the results may not be as reliable as they could be. Another test that can be used to test agility is the 505 agility test and this test was used in a study by Cochrane, Legg and Hooker (2004). This study looked at the short term effect of whole body vibration training on vertical jump, sprint and agility performance. Even though the 505 agility test is considered a valid assessment of agility (Cochrane *et al.,* 2004), it is a test of 180 degree turning ability which is a movement pattern not frequently seen much in the game of tennis, which means it would not be suited for testing agility in tennis.

Comparing all of the aforementioned agility tests, the t-test is more suited to testing tennis agility. This is because the athlete is always facing the same way, so is similar to the way the athlete will always try and face the net whilst playing, and also the left and right shuffling is a very common movement in tennis. In addition Pauole, Madole, Garhammer, Lacourse and Rozenek (2000) verified the validity and reliability of the t-test with regards to measuring linear to lateral agility after testing a variety of fitness components. When carrying out the agility tests it is essential to know how many times the tests should be carried out to get reliable data. In the study carried out by Miller *et al.* (2006) which looked at the effects of a six-week plyometric training programme on agility, the participants performed the agility tests three times. Also, in a study which looked at the effect of plyometric training on the agility of students enrolled in a college badminton programme (Heang, Hoe, Quin & Yin, 2012) the participants performed the agility test three times and the average result was considered. Making the participants carry out the base line testing three times is a common trend in many studies and thus appears to be a reliable number of times to carry out the agility t-test.

When carrying out agility tests it is important to be able to collect accurate timings. A study completed by Hetzler, Stickley, Lundquist and Kimura (2008) looked at the reliability and accuracy of handheld stopwatches (HHS) compared with electronic timing (ET) in measuring sprint performance. ET was used in this study to determine the reliability of HHS in timing each 25-metre split of a standard 200-metre sprint performance. Hetzler *et al*. (2008) states that faster runners may be more difficult to time accurately using HHSs, thus increasing the possibility for timing errors. Also in applications requiring a higher level of precision or in measuring times for small population sizes and individuals, the difference between mean and absolute error size may preclude the use of HHSs. Therefore, ET may be more suitable when measuring the times for a small population, as they will enable more accurate, reliable data to be collected.

2.7 Sample

In many studies, which have looked at the effects of balance training, a mixed sex sample group was used. Heitkamp *et al.* (2001) had 15 participants complete the balance training, of which eight were females, which means the ratio of men to women was not even. Yaggie and Campbell (2006) used in their study 36 healthy recreational active volunteers but it was not made clear whether these participants were male or female. Having mixed sex groups would make it harder to apply any findings to training groups, as it would be unclear whether it was men or women that influenced the results.

Previous studies, which used balance training for an intervention programme, used participants who were involved in a variety of sports. The participants used in the study carried out by Heitkamp *et al.* (2001) used to participate in a range of sports including jogging, dancing, handball, badminton, volleyball, table tennis and tennis. Using participants who are involved in a number of sports makes it hard to apply any findings to sport specific training. Some studies did use participants who were only involved in one sport but quite often this sport was football, for example in Gioftsidou *et al.* (2012) and Soderman, Werner, Pietila, Engstrom and Alfredson (2000). However there are very few studies that look at balance training with participants involved in just one sport, especially tennis.

2.8 Rationale

In conclusion it is clear that both balance and agility are important components in tennis, but there is very little research into how balance training could help to improve agility. Existing research has only looked at how balance intervention programmes can improve factors like functional and postural control, vertical jump height, shuttle run time and muscular strength and there is very limited research into what areas can help to improve agility apart from agility training. It would be beneficial to see if balance training can help to improve agility as Renstrom (2002) states that injuries in tennis can be due to inherent demands of the sport such as agility. Therefore, being able to improve agility may also help to reduce injury rates. Being able to reduce injury rates and prevent common injuries like ankle sprains, which can cost countries up to €187,200,000 to treat, may result in substantial monetary benefit (Verhagen *et al.,* 2010) and less time missed from playing tennis. Therefore, the proposed study will aim to investigate balance training as a prehabilitation intervention.

Previous research into balance intervention programmes showed improvements from anywhere between three to six weeks (Gioftsidou *et al.*, 2012; Heitkamp *et al.,* 2001). However, when the intervention was run for a shorter duration, more sessions were held a week (Gioftsidou *et al.*, 2012), therefore the current study will run for six weeks and have one session a week as this requires less commitment from the participants, in the hope that the participants will attend all the required sessions. The exercise and progressions for the current programme will be chosen using existing balance studies and various rehabilitation sources (Soderman *et al.,* 2000; Brukner *et al.*, 2012; Houghlum, 2005; McKeon *et al*. 2008). In the circuit, apparatus like wobble boards, balance cushions and bosu balance trainers will be used to challenge balance and proprioception and also training on unstable devices might enhance performance by improving proprioception (Cug, Ak, Özdemir, Korkusuz & Behm, 2012). The participants that will be involved in the study will be male university tennis players as there are limited studies that just look at one sport, and using a single sex group will make it easier to get more participants as there are more male Cardiff Metropolitan University players than females. Having more participants will make the results more reliable. The base line testing will involve the participants doing an agility t-test as it is easy to administer and Pauloe *et al*. (2000) verified the validity and reliability for the t-test in regards to measuring linear to lateral agility. When carrying out the agility t-test the participants will be required to carry out the test three times as in the studies carried out by Miller *et al.* (2006) and Heang *et al.* (2012) as this will provide more reliable data. So the proposed study will aim to investigate balance training as a prehabilitation intervention examining the effect on agility in male tennis players with no injury problems.

2.9 Hypothesis

Null Hypothesis (H0)- The six week balance intervention training programme will have no statistically significant effect upon agility performance in male Cardiff Metropolitan University tennis players.

Alternative Hypothesis (H1)- The six week balance intervention training programme will have a statistically significant effect upon agility performance in male Cardiff Metropolitan University tennis players.

CHAPTER THREE

METHODOLOGY

3.0 Methodology

3.1 Introduction

A six week controlled balance training programme was developed to determine any significant effects upon performance enhancement regarding agility, as a potential injury preventative procedure. There were two groups involved in the study in order to ascertain the true extent of any significant performance gains. The two groups were the control group (group one) and the experimental group (group two). Both groups undertook an agility T-test, after which group two completed a six week balance training programme. After the six weeks of balance training was complete, both groups were re-tested, using the agility T-test.

3.2 Participants

The study focussed on male students between the ages of 18-25 attending Cardiff Metropolitan University. The 16 participants were members of Cardiff Metropolitan University tennis club and attended tennis training at least once a week. There were eight participants in the control group (group one) and eight participants in the experimental group (group two). The participants were assigned to each group by their availability. If a participant knew they would not be able to attend balance training once a week, for six weeks, they were assigned to group one and if they knew they were available to attend balance training every week, they were assigned to group two.

Prior to partaking in the study the participants read the information sheet (Appendix A), which included the inclusion and exclusion criteria (table 1). One of the exclusion criteria was that the participants had not sustained a lower limb injury in the last 12 months. A lower limb injury was defined as a problem requiring reduction or interruption of full sporting or exercise activity for any length of time, with or without evaluation or treatment by a health care professional (Pluim *et al.,* 2006). Once the participants had read and understood the information sheet and made sure that they were eligible to partake, the participants read, agreed and signed an informed consent form (Appendix A).

Table 1. Inclusion and exclusion criteria for the study

Inclusion Criteria	Exclusion Criteria
Must be between the ages of 18-25 (inclusive)	Are not between the ages of 18-25 (inclusive)
Must undertake at least one tennis training session a week.	Do not undertake at least one tennis training session a week.
Must not have sustained a lower limb injury in the last 12 months.	Have sustained a lower limb injury in the last 12 months.

3.3 Procedure

After consent was gained from each participant, both the control (group one) and experimental (group two) groups completed the agility T-test. Before completing the T-test the participants carried out their standardised tennis warm-up, and the T-test was explained to them. The participants were allowed one practice run of the T-test but just at walking pace, to ensure they understood what the test involved. The participants completed the T-test three times, with two minutes rest between each test. Once the pre-test was completed, the control group were instructed to continue their normal exercise regime whilst the experimental group began the balance training programme. It was made clear to participants that they had no obligation to complete the exercise programme and could drop out at any time.

A full copy of the programme is shown in Appendix B, which was devised and supervised by the investigator. The programme lasted six weeks and was carried out once a week. This programme was chosen as it required the least time commitment from the participants, therefore ensuring they attended all balance training sessions. Following the six week training programme participants from both groups were re-tested using the agility T-test. Table 2 shows a schedule for the data collection and training programme.

Table 2. Schedule for data collection

Group	Week commencing 29th October	Six Week Programme	Week Commencing 10th December
1. Control (N=8)	Agility testing (T-test) completed	No programme. Participants carried on with their normal activities and training)	Agility testing (T-test) completed
2. Experimental group (N=8)	Agility testing (T-test) completed	Participants carried on with their normal activities and training, but also carried out six weeks of balance training.	Agility testing (T-test) completed

3.4 Setting

All agility testing took place in Cardiff Metropolitan University tennis centre and the balance training programme took place in the National Indoor Athletics Centre (NIAC) at Cardiff Metropolitan University. A risk assessment was carried out prior to the agility testing (Appendix C). All sessions were supervised to ensure the participants' safety, as well as making certain that the exercises were performed correctly.

3.5 Instruments/ Baseline testing

The agility T-test was carried out before and after the balance training programme by both groups. The T-test was set up as illustrated in figure 2 and the specifics of how the T-test was set up and conducted can be found in Appendix D. Each participant reported to Cardiff Metropolitan University Tennis Centre dressed in sporting attire, ready for testing. The agility T-test was explained to each participant and they were allowed one trial run through at walking pace. This was followed by the participants completing the T-test three times, with two minutes rest between each test. In letting the participants have a trial run it was hoped they would be more familiar with the testing procedure, thus ensuring the validity of the results.

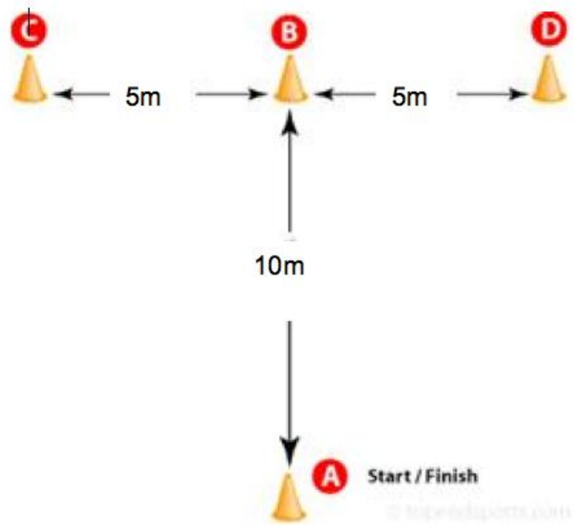

Figure 2: Agility T-test set up

3.6 Exercise Programme

The exercise programme for the experimental group (group two) consisted of one session a week for six weeks. Each session lasted 20 minutes and consisted of a circuit made up of eight different stations. Each participant started on one station and did a minute of work on that exercise and then had a minute of rest before moving onto the next station. The investigator kept time and told the participants when to start, stop and move onto the next station. Each participant carried out each exercise in the circuit once. In the circuit, apparatus like wobble boards, balance cushions and bosu balance trainers were used. Exercises were progressed every two weeks by increasing the difficulty of the exercise. Details of the circuit, exercises and progressions can be found in Appendix B. Attendance of the exercise programme was recorded manually. If a participant did not attend, or was unable to take part, the reason was noted as injured, ill, or absent, moreover if a participant missed more than one session they were excluded from post-testing.

3.7 Data Analysis

Statistical analysis of the data was performed using SPSS Statistics version 17.0 (SPSS Inc, Chicago, Il, United Stated of America) to identify whether there was a significant difference between pre and post agility T-test scores in the experimental group and the control group. Using SPSS an independent paired sample t-test was executed to initially identify if the groups (control and experimental) were matched or unmatched. This was so that if significant results developed, there would be statistical evidence to prove any changes that occurred were due to the six week intervention. Finally, to see if there was a difference in performance gains between the control and experimental group, a two-way mixed model analysis of variance (ANOVA) was carried out. This test examined for differences in performance in the agility T-test between the experimental group and the control group.

CHAPTER FOUR

RESULTS

4.0 Results

All participants met the criteria for this study when completing the participant information sheets and informed consent forms, giving a final sample size of 16 males *(n = 16).* All participants attended both pre and post testing: none were excluded due to lack of attendance, injury or illness.

4.1 Pre Intervention Agility Scores

Before the six week intervention programme the mean scores for the pre experimental and control group were as follows (Table 3):

Table 3: Mean scores and standard deviation for control and experimental groups pre testing

	Pre Control Group (s)	**Pre Experimental Group (s)**
Mean time	10.32	10.05
Standard deviation	0.56	0.56

To see if the pre mean scores for the two groups were matched at baseline an independent t-test was carried out. The results of the independent t-test were t (18) = 1.705, p = 0.095 (p > 0.05). These results indicate that the control and experimental group's pre scores were not significantly different at the outset of the study.

4.2 Pre to Post Scores

From table 4 and figure 3 it can be seen that there was a decrease in agility times for both the control and the experimental groups from pre to post testing. The difference in pre to post testing agility times is greater in the experimental group compared to the control group.

Table 4: Mean Agility Times for Control and Experimental Groups, Pre to Post Testing

Pre Control (s)	Post Control (s)	Difference Pre to Post (s)	Pre Experimental (s)	Post Experimental (s)	Difference Pre to Post (s)
10.32	10.19	0.125	10.05	9.72	0.3328

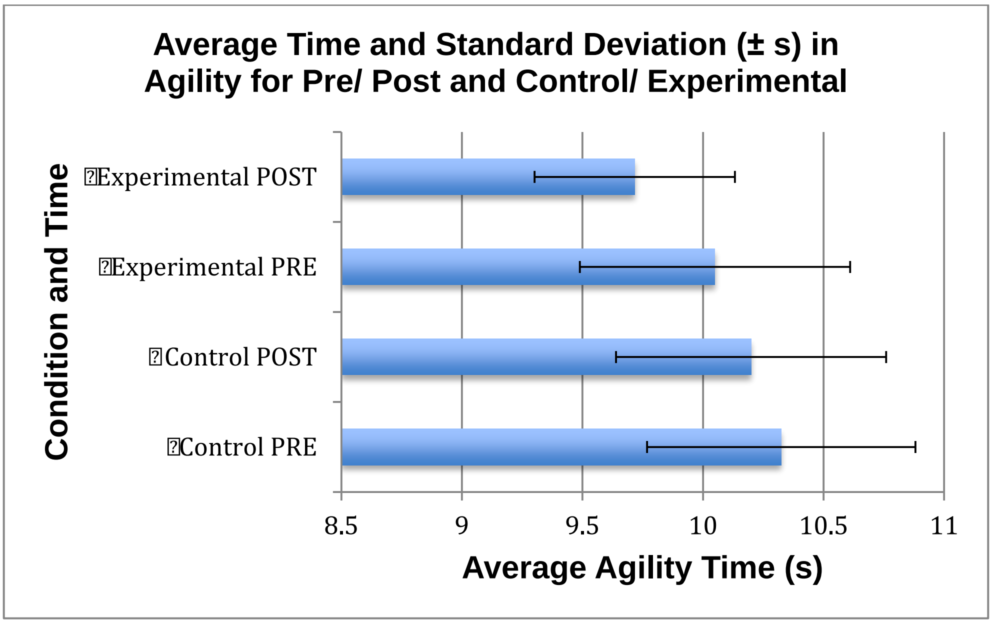

Figure 3: The mean and standard deviation (±SD) for conditions and time for the agility test.

4.2.1 Two-way Mixed Model Analysis of Variance (ANOVA)

Through calculating a two-way mixed model ANOVA the results show that there was a significant difference (p= 0.001*, $p < 0.05$) of the agility times in pre to post training when the control and experimental group scores are grouped together. But when the intervention is taken into consideration, the balance training did not have a significant effect on the agility times (p= 0.90, p> 0.05) post the six week intervention period. Even though the results were not significant, it was mentioned earlier, and can be seen in figure 3 that the experimental groups agility times improved more than the control groups agility times.

Table 5: SPSS ANOVA Results for the Agility T-test.

Tests of Within-Subject Effects	**F. Value (*F*)**	**Sig. Value (*p*)**
Training (Pre to Post results)	14.54	0.001*
Training and Group (Pre to post results with intervention taking into consideration)	2.99	0.90**
* = results are statistically significant ($p < 0.05$) ** = results are not statistically significant ($p > 0.05$)		

CHAPTER FIVE

DISCUSSION

5.0 Discussion

Within tennis, both balance and agility are important components of fitness, but there is little research into how balance training can help to improve agility. Existing research has only looked at how balance intervention programmes can improve factors like functional and postural control, vertical jump height, shuttle run time and muscular strength and there is very limited research into what areas can help to improve agility apart from agility training. With this in consideration, the current research aimed at investigating the effects of a six week balance training programme on improving agility in male tennis players. The following section analyses the principle findings of this research, and strengths and weaknesses of the study will also be addressed.

5.1 Principle Findings

Null Hypothesis (H0)- The six week balance intervention training programme will have no statistically significant effect upon agility performance in male Cardiff Metropolitan University tennis players.

Alternative Hypothesis (H1)- The six week balance intervention training programme will have a statistically significant effect upon agility performance in male Cardiff Metropolitan University tennis players.

The results of this study demonstrate that following a six week balance intervention training programme agility times did not significantly improve, meaning the null hypothesis can be accepted and the alternative hypothesis rejected. After performing a two way mixed model ANOVA it was clear that there was a significant reduction in agility times pre to post testing, but there was not a significant interaction between groups (F = 2.998, p= 0.90) (p> 0.05). Even though these results were not significant, there was a reduction in agility times with both groups and group two, who carried out the balance training, had a greater reduction in mean agility time compared to group one. The decrease in agility times within both groups could have been due to a change in the participants' normal routine and activities undertaken. Also the decrease in both groups agility times could be due to the participants becoming more familiar with the agility t-test testing procedure, meaning the learning effect could have been responsible for the reduction in agility time.

5.2 Recreational Activity

It was found the agility times decreased in both groups. This improvement in pre to post results could be due to other activities the participants undertook in the six week intervention period. Agility has relationships with trainable physical qualities such as strength, power and technique, as well as cognitive components such as visual-scanning techniques, visual scanning speed and anticipation (Sheppard & Young, 2006). So, if any participants had made improvements in any of the previous mentioned trainable physical components or cognitive components, from carrying out other physical activities, they may have had improvements in their agility times post the six week intervention period. To try and avoid agility improvements being a result of other physical activities, the participants would have to be asked to carry out no other physical activity during the six weeks of the study.

5.3 Intervention Content

As mentioned earlier, there was not a significant decrease in agility times as a result of the balance training programme, but group two agility times had decreased a little after the six weeks. The content of the balance training programme used equipment such as wobble boards, balance cushions and bosu balance trainers, which are known to challenge balance and also training on these unstable devices might enhance performance by improving proprioception (Cug *et al.,* 2012). The programme followed by the experimental group contained exercises similar to that of previous studies containing balance and proprioceptive training (Soderman *et al.,* 2000; McKeon *et al.,* 2008). These two studies plus the present investigation provided reliability and effectiveness for the exercise protocol showing improvements in the fitness component being tested; however it is only the present study that did not demonstrate statistically significant improvements within agility. This may have been due to the fact that the exercises, and progressions included in the present study were aimed around balance and tennis specific movements, but none of the balance exercises were agility specific.

Having a small, insignificant decrease in agility times may also be linked to the training intensity and duration of the present study. The length of a clinical programme is of high importance to researchers, doctors and therapists as it is vital to gain a sufficient effect in the minimum training period possible (Matsusaka, Yokoyama, Tsurusaki, Inokuchi & Okita*,* 2001). Yaggie and Campbell (2006) had significant improvements in joint proprioception, shuttle run times and reducing postural sway after a four week balance training programme and McKeon *et al.* (2008) also had significant improvements in self reported function, static control and dynamic postural sway in just four weeks of balance training. However Heitkamp *et al.* (2001) had significant results from balance training after six weeks of training. This indicates that six weeks of balance training is a substantial time for significant results to develop. However, in the present study significant results were not obtained after six weeks of balance training, which could be due to the lower intensity of the training programme. In those studies showing improvements at or prior to six weeks (McKeon *et al.*, 2008; Heitkamp *et al.,* 2001), the participants carried out 12 training units in the allocated time. This is double the amount of training units that was carried out in the current research, where only six training units were completed. So, even though group two had quicker agility times compared to group one after the balance training programme, this less intense training programme which was implemented in the current research may have been one of the contributing factors to the insignificant results.

5.4 Base line testing

The base line testing procedure that was used was the agility t-test. This testing protocol was chosen as it is used to determine speed with directional changes such as forward sprinting, left and right shuffling, and backpedalling (Miller *et al.,* 2006), common movements in tennis. Even though the results were not significant it was clear that the participants agility times had reduced after the six weeks of balance training. Sheppard and Young (2006) states though that while the agility t-test mimics the movements made in sport, the test needs to be unplanned to be more realistic, which the agility t-test is not. To provide more realistic results on whether the participants agility had improved it may have been better to use a different agility test, which is unplanned where the participants react to a stimulus, for example a light or a person.

Furthermore, even though the participants' agility times did improve, it is unclear whether this improvement was due to the balance training or other activities as balance was not tested at baseline or after the six week intervention period. To overcome this in future investigations, it would be better to test both agility and balance pre and post the intervention period. Gioftsidou *et al.* (2012) carried out a study that looked at balance training programmes for soccer injury prevention. There were two different testing measures used to see if there were improvements in balance after a three or six week intervention period. These were the Biodex stability system, which is a postural stability assessment and training system that assesses the ability of the body to balance on an unstable platform, and a wooden balance board with hemi-cylindrical bottom surface (Gioftsidou *et al*., 2012). Both of these balance measures use an unstable surface, which may not be a suitable way to see if balance has improved in tennis players. This is because tennis is never played on an unstable surface, and also the agility t-test that was used in the present study is also not carried out on an unstable surface.

A more appropriate means of measuring balance, if it had been used as a baseline measure in the current study, would have been the Star Excursion Balance Test (SEBT) or the Y-balance test (YBT). Both of these tests are performed on stable surfaces and involve the participant standing on one leg in the centre of a grid, and reaching with the free limb in given directions, as far as they can. Valovich McLeod, Armstrong, Miller and Sauers (2009) used the SEBT as one of the measures of balance as the reliability of the test is excellent for both intertester and intratester reliability (Valovich McLeod *et al.,* 2009). As the SEBT and YBT are almost identical tests, it is likely that the YBT is also highly reliable as a measurement tool. Either of these tests would have been suitable to measure the participants' balance both pre and post the six week intervention as they are easy to administer and quick to complete. Measuring balance as well as agility performance would mean that it would be easier to see if the improvements in agility performance are a result of improvements in balance obtained from the balance training programme.

5.5 Participation Level/ Subject Population

When observing the mean times for pre control and experimental scores for the agility t-test, both groups demonstrate notably high baseline measures, indicating high agility ability. This could be due to the testing starting part of the way through the tennis season, so the participants would have already been carrying out some agility training alongside their normal tennis training. Also as the present research specified that subjects had no history of lower limb injuries in the past 12 months, none of them had any balance or agility deficits due to recent previous injuries. Therefore the study proposes that there is a reduced chance of great improvements to develop for any of the participating subjects within a six week period. Zech, Hubscher, Vogt, Banzer, Hansel and Pfeifer (2010) also state that the scope for balance training effects are predominantly significantly higher in untrained and non-athletes compared to athletes participating in various sports. This is because athletes participating in various sports previously possess sound proprioceptive control. This means in the current study the participants, who are all tennis players, would have better proprioceptive control, which could help with balance and agility performance.

The participants that were involved in the study were all Cardiff Metropolitan tennis players. The sport or training that an individual partakes in can greatly affect their initial proprioceptive levels as each sport provides unique sensorimotor challenges (Bressel, Yonker, Kras & Heath, 2007). Using tennis players as the participants in this study, who already had high levels of agility, may have been one of the reasons that the results obtained were not significant. Future research could use recreational athletes to see whether a balance training programme can improve agility. Using recreational athletes as the participants would mean that improvements in results would be more apparent as their previous skill level will be lower due to their sensorimotor skills not being challenged as often and at such a high level.

5.6 Limitations

5.6.1 Sample Number/ Sample Type

The number of participants in this study (*n*=16) is small which greatly affects the reliability of this investigation, making it difficult to generalise the results to a population as a whole (Fields & Hole, 2008). Thus in future research a larger sample size is required. Zech *et al.* (2010) confirmed that the larger the sample size, the stronger the data is, as the reliability and validity of the results is a lot stronger. Also it would be beneficial to include participants from different populations such as including different ages, genders and participants from different sporting backgrounds. This would provide a better understanding of the populations in whom balance training does have a positive effect on agility.

5.6.2 Anthropometric Data

Stature and body mass were not measured at any point during this study. This anthropometric data should be considered in future research as each of these could affect the results. An increase in body weight and height correlates with greater balance instability (Hue *et al.,* 2007) and greater amounts of body fat can reduce sprinting performance (Perez-Gomez *et al.*, 2008), which could affect participants performance in the agility t-test. In future studies basic anthropometric data should be recorded to identify whether stature and body mass contribute to improvements in agility times following a six week balance training programme, or whether these can be excluded as confounding factors.

5.6.3 Injury Relation

Although this study showed a trend towards improvements in agility after the six weeks of balance training, it is still unclear whether balance training directly affects injury rates within tennis, by improving agility. It is important to try and improve agility through balance training as inherent demands of tennis, like agility and strength can cause microtrauma injuries (Renstrom, 2002). Therefore, future research could investigate the use of an injury report system as well as balance training to establish whether the balance training, can improve agility, and therefore aid in reducing injuries within tennis. For the results of such an investigation, the study would have to be carried over a much longer period, and both tennis matches and training would have to be monitored.

5.7 Reliability

The method used in the current study was used to try and ensure that the results were as reliable as possible. All the participants carried out the agility t-test on exactly the same day of the week pre and post the six week training period, in the same place and were ask to carry out the same daily routine on both days. Being asked to carry out the same daily routine on both days means that the participants are carrying out the agility t-test under the same conditions, so no other factors should be influencing the results. As the participants' daily routines were not monitored though, it is unknown whether they did carry out the same routine and if whether certain psychological and physiological factors, like anxiety, fatigue and stress, were present and influenced the results.

The experimental group carried out the balance training at the same time on the same day each week, for the six weeks. This was to try and make sure the balance training was being carried out under the same physiological and psychological condition each time. Again, by not monitoring the participants' daily routine it is unknown whether the balance training was being carried out under the same conditions, and whether other factors, like fatigue from training affected the results. If the study were to be carried out again, better monitoring of the athletes daily routine would have to be carried out to make sure no other physiological and psychological factors influence the results. This would mean if the study was replicated, results would be consistent and more reliable.

5.8 Practical Implications

Training intensity was very low and considered one of the limitations of the current study with regards to agility performance. There were however improvements in agility performance (not significant) within both groups post the six week intervention period, and the experimental group, who carried out the balance training, improved by the most. Through implementation of 12 balance training units within the intervention period (four to six weeks), studies have found statistically significant performance gains in certain areas like proprioception, shuttle run times, self reported function and static and dynamic postural sway (McKeon *et al.*, 2008; Heitkamp *et al.,* 2001). Therefore if the number of balance training sessions a week were to increase, it seems reasonable to suggest that greater improvements would be observed, meaning balance training could be seen as beneficial for agility improvements. Also as there were slight improvements in agility performance in the current study, the type of balance training programme that was used could be implemented into a practical setting, for example tennis training. However, as the study only included male tennis players these results cannot be generalised to other populations. Before implementing this type of programme within other populations more research should be done.

5.9 Future Recommendations/ Studies

The programme devised within the current study showed a trend towards effectiveness in gaining improvements in agility within tennis. Therefore to further advance research within balance training as a single intervention, it would be beneficial to see how balance training can affect other tennis fitness components, not just agility. Testing other fitness components, like speed, balance, strength and jumping ability, which are common in a lot of different sports, would mean that if improvements were seen, the balance training programme could be used for training a number of different fitness components. It could also then be used amongst other sports training programmes, not just tennis. Also any performance enhancements established from carrying out a balance training programme could provide evidence for balance programmes to be implemented as a prehabilitation and injury prevention tool across a variety of different sports.

To make future studies more reliable a sample size larger than 16 participants should be used as Zech *et al.* (2010) confirmed that the larger the sample size the stronger the data is, as the reliability and validity of possible results is a lot stronger. Also participants with different tennis backgrounds could be used as the current study only looks at university tennis players. Using tennis players, which have different sporting backgrounds and are of different levels, gender and ages, could help to see whether results vary across different populations. This would help to indicate whether a balance training programme is an effective training mechanism with all types of tennis players. Also previous research looks at sporting individuals and there are not many studies that look at recreational athletes. To further advance research within balance training as a single intervention, recreational athletes could be used. Using recreational athletes would mean if the balance training programme was found to significantly improve certain fitness components, it could then be used across a wider population and more sports. If the sample size was also to be increased it could be beneficial to compare recreational athletes with top sporting athletes. This would indicate whether having a baseline of sound proprioceptive control and good balance prior to testing, affects the level of improvement that can be gained in certain fitness components.

In summary this study provides support that balance training increases agility performance within male tennis players, but not by a statistically significant amount. For future research, other fitness components should be tested, not just agility and a larger population of either other tennis athletes or recreational athletes should be used. This would mean that there would be clearer evidence as to in which sports, and in which populations balance training improves agility performance, and where incorporation of such a programme would be of benefit to the individuals.

CHAPTER SIX

CONCLUSION

6.0 Conclusion

The current study aimed to investigate the effect of a six week balance training programme on agility in male tennis players. Agility was investigated, as agility is one of the inherent demands of tennis that causes microtrauma injuries. Looking at one of the most prevalent injuries in tennis, the ankle sprain, it is clear that treating these injuries can cost substantial amounts of money. Verhagen *et al.* (2010) found that sport related ankle sprains cost the Netherlands €187,200,000 in just one year. Being able to improve a player's ability to cope with inherent demands like agility, could reduce his or her chance of sustaining an injury, and would reduce the amount of money spent on treatment.

The results from the current study did not show significant improvements in agility performance after carrying out balance training for six weeks. Even though the results were not significant, the experimental group agility times did improve by a larger amount from pre to post testing, compared to the control group agility times pre to post testing. These results are encouraging and more research is needed. If indeed balance exercises and equipment can lead to performance enhancement and therefore decreased injury rates, this type of programme could form a useful part of training in various settings. The results also showed that there was an improvement within the control group. This may have been due to improvements in other areas from additional activities the participants were undertaking in the six weeks, as agility has relationships with trainable physical qualities such as strength, speed and technique (Sheppard & Young, 2006).

Previous research shows that significant improvements in trainable physical qualities can happen at or prior to six weeks of balance training (McKeon *et al.*, 2008; Heitkamp *et al.,* 2001). These studies that gain significant results in the same or less time than the current study implement a more intense training programme as 12 training units are carried out, rather than the six training units that were carried out in the current research. If the study was to be repeated a more intensive training programme should be devised, as it is more likely that significant improvements in agility performance would be seen. Another reason there were no vast improvements in agility performance may have been due to the high baseline measures of the participants. All the participants were Cardiff Metropolitan Tennis Players, and the testing started part way through the tennis season, meaning agility training would have already been carried out in their normal training session. Also none of the participants had sustained a lower limb injury in the last 12 months, meaning they should not have any noticeable deficits in balance or agility.

The current study used the agility t-test to test the participant's agility. Sheppard and Young (2006) state that while the agility t-test mimics the movements made in sport, the test needs to be unplanned to be more realistic. Also to confirm that the agility improvements made by the participants were due to the balance testing it would have been beneficial to have also tested balance pre and post the six week intervention period, using a balance test like the Y-balance test or the Star Excursion balance test (Valovich McLeod *et al.,* 2009). As well as not testing balance at baseline level, the results are limited in that the sample size is small and only uses male tennis players, and also anthropometric data has not been looked at in the study.

Taking into consideration that the sample size was small in the current study it would be beneficial to use a larger sample size in future studies as Zech *et al.* (2010) confirmed that the larger the sample size, the stronger the data is, as the reliability and validity of possible results is a lot stronger. Also, using recreational athletes in future studies, and not just tennis players, would mean that if the balance intervention programme was found to significantly improve certain fitness components, a similar training programme could be used across a wider population and within more sports. Comparing recreational athletes to top sporting athletes would also indicate whether having higher baseline balance ability, affects the level of improvement that can be obtained after carrying out a six week balance programme. Finally to further enhance research, it would be advantageous to see how balance training affects other fitness components within sports, not just agility. Testing other fitness components, such as speed and strength, would mean if improvements were seen, balance training could be used in a lot more training situations.

As a result of the six week balance training programme, positive improvements in agility within male tennis athletes were apparent. Based on this, balance programmes should be considered among sporting populations as improvements in balance and agility could have an effect on injury prevention and possible performance enhancement.

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APPENDICES

APPENDIX A

PARTICIPANT INFORMATION SHEET AND INFORMED CONSENT FORM

Research Participant Information Sheet

Project Title: 'Does Balance Training Have an Effect on Agility in Tennis?'

This document provides a run through of:

1) the background and aim of the research,
2) my role as the researcher,
3) your role as a participant,
4) benefits of taking part,
5) how data will be collected, and
6) how the data / research will be used.
7) Inclusion/ exclusion criteria

The purpose of this document is to assist you in making an *informed* decision about whether you wish to be included in the project, and to promote transparency in the research process.

1) Background and aims of the research

Within tennis, injury rates are very high, with most being in the lower body (ankle and knee). Decreased agility has been found to be a cause of injuries within tennis, but there is not much research on how different training can help to improve agility, and therefore reduce the risk of injury.
We (me and my research team) wish to see whether there is relationship between balance training and improving agility, and therefore reducing the risk of injury.

2) My role as the researcher:

The study involves me (Sarah Thomas) to carry out a pre and post agility test (t-test) on all participants and also to carry out a six week balance training programme on half of the participants (Group 2).

3) Your role as a participant:

Your role is to complete a pre and post agility test, which will be a simple T-test. Group 1 will undertake their normal training for the six weeks between these tests. Group 2 will be required to undertake a six week balance training programme on top of their normal training programme. The balance training will involve two 30 minutes sessions a week.

4) Benefits of taking part:

The information we obtain from this study will allow for better insight into whether balance training helps to improve agility and therefore reduce the chance of injury. From this it will be clear whether balance training should be a regular component of tennis training.
We will be happy to share this information to any of the participants of this study. On request, we can also provide you with details of your results from the agility tests to see whether you improved and how this may affect your performance and risk of gaining an injury.

5) How data will be collected:

The data from the agility t-test test will be collected using photo-electronic timing gates (Smartspeed, FushionSport, Brisbane, Australia). This system is more reliable and accurate than using a stop watch.

6) How the data / research will be used:

In agreeing to become a *voluntary* participant, you will be allowing me to use the data collected from your pre and post agility tests for my research. All the data collected will be anonymous.

7) Inclusion/ exclusion criteria:

Inclusion

- Must be between the age of 18-25 (inclusive)
- Must undertake at least one tennis training session a week
- Must not have sustained a lower limb injury in the last 12 months

Exclusion

- Are not between the age of 18-25 (inclusive)
- Do not undertake at least one tennis training session a week
- Have sustained a lower limb injury in the last 12 months

Your rights

Your right as a *voluntary* participant is that you are free to enter or withdraw from the study at any time. This simply means that you are in full control of the part you play in the study.

Protection to privacy

Concerted efforts will be made to hide your identity in any written transcripts, notes, and associated documentation that inform the research and its findings. Furthermore, any personal information about you will remain *confidential* according to the guidelines of the Data Protection Act (1998).

Contact

If you require any further details, or have any outstanding queries, feel free to contact me on the details printed below.

Sarah Thomas
ST10001836@outlook.cardiffmet.ac.uk

Cardiff Metropolitan University
Informed Consent Form

CSS reference number:

Title of project: ‘Does Balance Training Have an Effect on Agility in Tennis?

Name of researcher: Sarah Thomas

Participant to complete this section: Please initial each box.

1. I confirm that I have read and understand the information sheet for this study.
2. I have read and understood the inclusion and exclusion criteria
3. I have had the opportunity to consider the information, ask any questions, and had satisfactory answers to these questions.
4. I understand that my participation is voluntary and that it is possible to stop taking part at any time, without giving a reason.
5. I understand that if I stop taking part at any point, that my relationship with Cardiff Metropolitan University and my legal rights will not be affected.
6. I understand that information from the study may be used for reporting purposes, but I will not be identified.
7. I agree to take part in this study on ‘The affects of balance training on agility’

Name of participant……………………………………………………………………

Signature……………………………………………………………Date………………….

Name of person taking consent…………………………………………………………

Signature……………………………………………………………Date………………….

Email Address……………………………………………………………………………..

APPENDIX B

BALANCE TRAINING PROGRAMME

Balance Training Programme

The circuit consisted of eight stations. The participants started on one station and moved round the stations clockwise. The participants started on the same station number each week. Each station was carried out for one minute with a minute rest between each station. The circuit was completed once a week.

Week 1 and 2

1) Double leg stance on balance board
2) Single leg stance on balance board
3) Double leg dips on bosu board
4) Standing on balance cushion (eyes closed)
5) Single leg stance on balance cushion
6) Standing reaches
7) Sideways lunges off bosu board
8) Bounds over tramlines

Week 3 and 4

1) Double leg stance on balance board
2) Single leg stance on balance board with eyes closed
3) Single leg dips on bosu board
4) Slow alternate hops on balance cushion
5) Arabesque on balance cushion
6) Standing reaches whilst on balance cushion
7) Sideways lunges off bosu board onto balance cushion
8) Bounds over tramlines, over a cone

Week 5 and 6

1) Double leg stance on balance board
2) Single leg stance on balance board with eyes closed
3) Single leg dips on bosu board with medicine ball twists at bottom of dip
4) Slow alternate hops on balance cushion, whilst throwing and catching a ball to a partner

5) Single leg stance on balance cushion whilst extending free leg forwards, backwards and sideways
6) Standing reaches, whilst on a balance cushion, whilst holding a medicine ball with both hands
7) Sideways lunges off bosu board onto balance cushion with hands behind back
8) Bounds over tramlines, over a cone, and when land shadow a forehand or backhand

APPENDIX C

RISK ASSESSMENT FORM

RISK ASSESSMENT (RA99)		Page 1 (V3/07)	
School / Unit and Area:	Cardiff Met School of Sport Physiology department Tennis Centre	**Assessment Number:**	
Risk Assessment undertaken by: Recommended to be 2 or more people	Sarah Thomas	Sara Ruth Morgan	
Description of the work activity being assessed:	Agility T-test, using the timing gates, in the tennis centre		
Persons Affected:	Staff [ ] Students [x] Others [ ]		
Details of Others:			

	Hazards Identified Please provide details of the hazards associated with the area or task. **EXAMPLES INCLUDE:** Working at height, Manual Handling, Electricity, Fire, Noise, Contact with moving parts of machinery, Dust etc	**Risk Rating <u>without</u> Controls** The **R**isk **R**ating and Degree of Risk are determined by multiplying the **S**everity of injury by the **L**ikelihood of occurrence. Please see UWIC Risk Rating Matrix for details			
		S	**L**	**RR**	**Degree of Risk**
1	Tripping over tennis equipment left on court. Equipment such as tennis balls and racquets.	1	1	1	Low level of risk, but still requiring periodic monitoring and review
2	Tripping over the netting at the sides of the tennis courts	1	1	1	
3					
4					
5					
6					
7					
8					
Risk is considered to be low so no further action was taken		**Date of Assessment 29/10/12**			

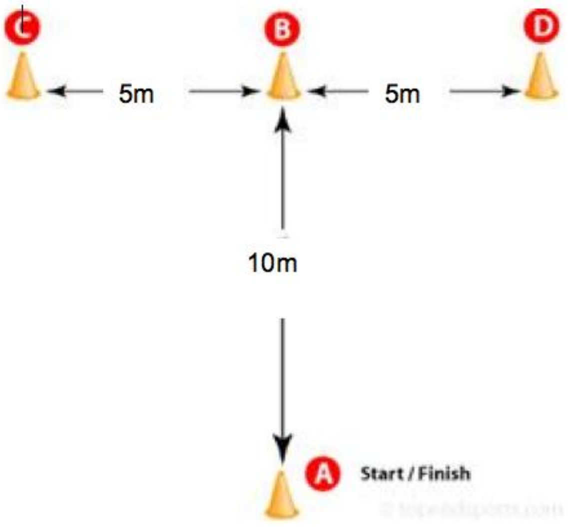
APPENDIX D

AGILITY T-TEST INSTRUCTIONS AND SET UP

Agility t-test instructions and set up

The cones are set up as illustrated in the image below, with Smartspeed gates situated either side of cone A. The Smartspeed system (Smartspeed, Fusion Sport, Brisbane, Australia) is activated using the PDA and when a constant green light is evident on the Smartspeed unit the participant can begin; the timing will start when the participant runs through the gate. The participant will start one metre behind cone A and will run and touch cone B, before side stepping to cone C and touching it with their left hand. The participant then sidesteps across to cone D and touches it with their right hand, then sidesteps back to cone B and touches it with either hand, before back pedalling (facing forward, and running backwards) to cone A. The timing will stop when the participant runs backwards through the timing gate at cone A.

Images during the study



APPENDIX E

PARTICIPANTS AGILITY RAW DATA

Participant's agility raw data

	Agility times (s)			Agility times (s)	
Participant coding	Control PRE	Control POST	Participant coding	Experimental PRE	Experimental POST
C2	9.809 9.8 9.666	10.078 9.729 9.687	E1	9.559 9.251 9.319	9.544 9.259 9.148
C3	10.976 10.556 9.997	10.308 9.971 9.817	E7	9.823 9.594 9.587	9.746 9.414 9.154
C4	10.292 9.444 9.576	9.645 9.532 9.688	E8	11.08 10.88 10.176	10.356 10.457 9.883
C5	9.754 9.85 9.515	9.966 9.749 9.867	E9	10.129 9.79 9.427	9.73 9.404 9.193
C6	10.386 11.021 10.418	11.715 11.217 10.433	E10	11.444 10.661 10.561	10.211 9.868 10.326
C11	10.577 10.587 10.685	10.23 11.008 10.317	E12	10.287 10.004 9.932	10.256 9.637 9.766
C14	11.27 11.243 10.684	10.633 10.474 10.942	E13	10.202 9.851 9.877	10.127 9.922 9.748
C15	10.938 10.452 10.289	10.045 9.933 9.802	E16	10.37 9.763 9.621	9.589 9.179 9.283

APPENDIX F

SPSS OUTPUTS

SPSS Outputs

Agility Independent T-test

Group Statistics

	Group Membership	N	Mean	Std. Deviation	Std. Error Mean
Agility Time	Control Group	24	10.3244	.55651	.11360
	Experimental Group	24	10.0495	.56054	.11442

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Agility Time	Equal variances assumed	.067	.796	1.705	46	.095	.27487	.16123	-.04967	.59942
	Equal variances not assumed			1.705	45.998	.095	.27487	.16123	-.04967	.59942

Two-way Mixed Model Analysis of Variance (ANOVA)

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Training	Sphericity Assumed	1.257	1	1.257	14.540	.000
	Greenhouse-Geisser	1.257	1.000	1.257	14.540	.000
	Huynh-Feldt	1.257	1.000	1.257	14.540	.000
	Lower-bound	1.257	1.000	1.257	14.540	.000
Training * Group	Sphericity Assumed	.259	1	.259	2.998	.090
	Greenhouse-Geisser	.259	1.000	.259	2.998	.090
	Huynh-Feldt	.259	1.000	.259	2.998	.090
	Lower-bound	.259	1.000	.259	2.998	.090
Error(Training)	Sphericity Assumed	3.978	46	.086		
	Greenhouse-Geisser	3.978	46.000	.086		
	Huynh-Feldt	3.978	46.000	.086		
	Lower-bound	3.978	46.000	.086		