Mark Dayson

Title: The relationship between baseline and physical performance screening tests, and game performance outcomes in elite youth basketball.

In part fulfilment for Professional Doctorate in Sport, Exercise and Health

Faculty: School of Sport and Exercise Sciences

For the award: Doctor of Sport

Student number	14906297
Word count	61,823

Declaration:
No part of this thesis has been submitted in support of an application for any degree or other qualification of the University of Kent, or any other University or Institution of learning.

Signature:

M.L.Dayson

Acknowledgements:

In these periods of intense study there are inevitably many people who help in various ways and so I would like to thank.

Firstly, a significant thank you to my supervisor Professor Louis Passfield. Louis has provided a balanced view enabling me to see the wood through the trees when at times the tussle between practical real world and strict academic scientific approaches seemed at logger-heads.

A very significant debt of gratitude to Dr Daniel Madigan who has helped to guide me statistically, thus avoiding the pitfalls beckoning with many variables of data. Dan has without doubt helped to progress my thoughts, mind and clarity on issues that were at the best of times cloudy.

Thank you to Canterbury Academy Institute of Sport for access to both facilities and athletes. Within this a special thanks to Jesse Sazant and the Academy basketball athletes and parents who gave permission for study inclusion without which the whole project would not have got off the ground.

Finally, to my family who must at times wondered how long I can sit in front of my laptop! I hope this will inspire my children to push their boundaries beyond their comfort zone. Thank you to my brother who not only edits but inspires and supports me. My partner Yuyang has encouraged me relentlessly and been a massive pillar of support.

Abstract.

Introduction: To date, limited research has examined the relationships between baseline (Range of Movement tests active, passive and loaded) and physical performance screening tests and game performance outcomes in elite youth basketball. Therefore, the experimental hypothesis for this thesis was that useful screening tests would correlate with selected game performance metrics. In addition to this, categorical data and injury correlations were considered. Tests were grouped according to their type (baseline, neuromuscular, upper limb, strength and endurance, speed and agility and jumps). The grouping allowed a clearer observation of the link between tests and game performance outcomes. The hypothesis for each group is that some tests would correlate to some game's performance outcomes. One example of this is that jump tests would correlate with both defensive and offensive rebounds. This exploratory study was primarily conducted to inform practice within elite academy basketball settings from a physiotherapy practice perspective.

Method: 19 elite youth male basketball players (Mean age = 17 years; range 16-19 years) performed a series of baseline range of movement and physical performance tests divided across three sessions. Baseline testing included passive and active range of movement at the ankle, hip and shoulder. Physical tests included upper limb stability and strength, vertical jumps, reactive and non-reactive agility, lower limb balance and neuromuscular control, speed tests and strength endurance tests of hamstring and core.

Results: A series of moderate and strong correlations were found between baseline range of movement (ROM), physical performance tests and some game statistic outcomes. Strongest correlations were found between offensive rebounds and shoulder passive internal rotation (Left r = .57, p < 0.01, Right r = .66, p < 0.01). Right hip passive internal rotation and free throw percentage (r = -.61 p < 0.01). Straight leg raise and free throws made (Right r = .74, p < 0.01, Left r = .62, p < 0.01). Straight leg raise and free throws season percentage (Right r = .65, p < 0.01). = r = -.56, p < 0.05, Left r = .52, p < 0.05). Right hamstring 90/90 correlated with free throws made (r = -.66, p < 0.01. Left hamstring 90/90 correlated with assists season average 9 r = -.66, p < 0.01). Left dorsiflexion with assists season average (r = -.61, p < 0.01). Right dorsiflexion passive correlated with 2 pt field goal percentage (r = -.62, p < 0.01) and defensive rebounds (r = -.64, p < 0.01). Qualitative assessment single leg squat correlated with Free throws made (Left r = .62, p < 0.01, Right .51, p < 0.05) and offensive rebounds (Left r = .61, p < 0.01, Right r = .47, p < 0.05). Side plank left correlated with defensive rebounds (r = -.70, p < 0.01). Closed kinetic chain upper extremity stability test (CKCUEST) correlated with with assists season average (r = -.72, p < 0.01). Agility T-Test correlated with number of games played season (r = -.62, p < 0.01), defensive rebound (r = -.64, p < 0.01) and total points season average (r = -.66, p < 0.01). No significant correlation was found between baseline testing and injuries

Discussion: The findings of the present study suggest that some baseline range of movement (ROM) and physical performance tests correlate with game performance outcomes in elite youth basketball. Understanding and interpreting the data and progressing testing protocols to fully integrate elements of sport specific movement and analysis is key to developing protocols that ultimately have a bearing on their relationship to game performance. The findings will have direct implication on applied practice as these results are used to adapt interventions and develop further testing.

Conclusion: Multiple correlations were found between baseline range of movement (ROM) and physical performance tests with season long game statistics. The findings from the present study can be used to elicit changes in practice so as to ensure tests provide information for performance as oppose to just baseline data for comparison.

Contents

Figures

Tables

Chapter 1

Introduction.

Musculoskeletal screening or pre-participation examination is widely used in sport across many disciplines and levels to determine a baseline measure and assess risk of injury (Fuller et al., 2006; Fuller et al., 2007) . These protocols are wide and varied ranging from baseline range of movement (ROM) testing, cardiovascular and medical screening (Brukner et al., 2004; Conley et al., 2014), to functional task based testing like the Functional Movement Screen (Cook et al., 2006a; Cook et al., 2006b) and include sport specific testing (Parsonage et al., 2014). For clarity across this thesis, Baseline tests refer to Range of Movement (ROM) in active, passive and loaded or functional positions.

Within my professional setting I apply a physical testing musculoskeletal protocol to the athletes. The protocol predominantly consists of range of movement, strength, balance, agility, power and strength endurance tests. These athletes are at an Elite Basketball Academy in the UK. The academy setting has approximately 140 athletes and performers inclusive of dance and musical theatre. Testing to date has been generic and therefore does not provide clear and detailed information on outcomes nor have they been followed up with plans to address what testing has found. Overseeing the testing protocols will enable me to evaluate all tests and decipher those that are useful and provide important information from those that are not time efficient or that do not provide efficacy. The evolution of screening and testing within the academy setting is expected to continue alongside this research and for some years beyond as I refine procedures in an attempt to ensure that all tests are administered for a clear reason. Currently athletes are predominantly screened to provide a set of baseline data that can be referred to in case of injury or compared to measure improvement across time. However, I acknowledge that injury prediction is not possible from screening outcomes alone and that to date the academy screening protocol has not provided a bridge between test performance and game performance. The bridge is a relationship I would like to understand and foster, that I believe will provide me with the first step in grasping the development of players needed to focus to enhance performance during game play. However, it should be acknowledged that a clear distinction between injury prevention and performance is difficult to achieve. Many factors impact on performance and clear correlations have been found on lower injury rates and performance outcomes across sports (Hägglund et al., 2013; Podlog et al., 2015). The ability to understand how screening and injury prevention protocols affect performance is critical when considering correlations between screening tests and performance, especially when each test is measured in isolation to each game statistic. So many screening and physical test make the development of injury prevention protocols difficult to measure against game performance but can be compared to epidemiology. This is the distinction between injury prevention protocols and performance. If I am able to develop tests that are closer to training and game-based movements, the inclusion and buy-in of staff and players is improved and can lead to greater integration within testing and indicate performance outcomes in games. Recent research suggests that resources are a barrier to coaches delivering Injury Prevention Protocols (IPP) and integration of a team approach including players and support staff may yield better adherence (Dix et al., 2020).

McGuine et al (2013) found in a study of high school basketball coaches, implementation of an ankle injury prevention study and prophylactic use of ankle braces that time, expertise and awareness of protocols alongside adequate space to deliver interventions were barriers. Some statement found during the McGuine (2013) study said coaches “didn’t think injury prevention programme helped having use it before”. This is reinforced by Norcross et al (2016) where 48% of respondents to their web-based survey were not aware of injury prevention programmes and there was no advantage over current coaching practice. To get full buy in coach education within my academy setting needs to be included for injury prevention as this develops. I would also suggest anecdotally that coaches do want to be able to see a link to screening and/or injury prevention to performance outcomes.

Wilke et al. (2018) considered head coach attitudes to injury prevention in German professional basketball and found some surprising insights. Only approximately one third of teams who responded used a physician (36.1%), physiotherapist (33.7%) or strength and conditioning coach (38.6%). This lack of expertise led to beliefs not associated with current scientific literature or opinions on importance of injuries or interventions. An example of this is both ankle sprains and knee injuries are considered more important than bone fractures. With interventions sports technique, movement patterns and stretching were deemed more important than education, knowledge of rules, orthoses and sprint ability (Wilke et al., 2018).

Academy coaches are educated and play a part in almost all sessions delivering our injury prevention protocols so would not have the same attitudes and beliefs as those outlined previously.

Physiotherapists and other professionals working within sport disagree on which screening protocols should be implemented (Kritz, 2012; Mottram & Comerford, 2008; Cook et al., 2006a; Cook et al., 2006b). This lack of consensus exists between professionals, both within sports and across different sports (Fuller et al., 2007) both in the UK and overseas (Brukner et al., 2004). Physiotherapists screening within a sport environment often utilize the Functional Movement Screen protocol (Cook et al., 2006a; Cook et al., 2006b) with the thought that it is functional. It has been widely used and applied in sports settings as a protocol that practitioners have followed without much questioning if there is a better alternative. This suggests there may be a lack of confidence, skills or choosing of an easy path from physiotherapists rather than the need to develop screening for their situation. Although Functional Movement Screen is a dynamic functional task, the test does neither replicate sport specific movements at training or game pace, nor provide pure baseline data. Thus, it does not allow physiotherapists to compare pre and post injury status. My personal experience highlights the lack of clarity on how Functional Movement Screen enhances baseline musculoskeletal and performance testing widely used. I would argue that although screening protocols use validated tests, the overall application and interpretation is problematic. The suggestion an athlete is at risk of injury because a protocol applies a numerical threshold of which they fall short is overly generic and does not, as a number, provide any information on athletes' shortcomings or risks. Practitioners would need to delve into each individual test to analyse and interpret not only the data but also the performance of the test itself. In essence, a re-test has to be completed unless there is multi-dimensional video available that can negate the numerical element of test results.

In a recent study, Bahr (2016) highlights significant differences in classic disease screening model (World Health Organization, Jungner & Wilson, 1968) versus sports injury screening. The differences in screening model establish if someone is healthy or not, for disease; or at risk, for sport. Secondly, in disease, treatment is the optimum intervention, whereas in sport the optimal strategy is an injury prevention programme (IPP) (Bahr, 2016). This fundamental aim to implement an injury prevention programme is an ethical challenge, as most athletes partake in one as part of their training and competition programme, therefore, could not have this removed as part of study. Additionally, the overlap in athletes who would be injured falling outside the screening tests cut off values and vice versa for those athletes uninjured falling within the high-risk category show that arbitrary cut of scores both encapsulate and miss with negative outcomes (Bahr, 2016).
Bahr (2016) highlights both modifiable and non-modifiable risk factors. Modifiable (those that we can change) are usually those targeted by screening tests, whereas non-modifiable are those we cannot change but may utilise to target interventions. Risk factors in sport are wide and varied and include, but not exclusive to physical, psychological, lifestyle and environmental. My academy setting and the age group within it makes some of these risk factors unknown. Can we as support staff truly know what our athlete’s diets are and how this impacts not only performance but also the screening test outcomes? Trying to

account for or control risk factors is considered but as a collective staff group know we cannot control all elements.

Specificity and sensitivity are inversely related meaning if we want to identify all injured players then inevitably uninjured players will be captured to due to the sensitivity required. This makes the actual cut off value extremely difficult to accurately predict. Bahr (2016) has outlined three critical steps to progressing screening tests.

1. Strong relationship between marker and injury risk.
2. Relevant populations must be used for applied tests.
3. Documentation that a screening protocol intervention is of greater benefit than an intervention in isolation.

This is why research must look at how tests and athlete movements during testing relate to epidemiology and performance game statistics rather than attempting to predict and understand if the screening or intervention is the magic tool in reducing injury. This dual pronged approach to musculoskeletal pre-participation screening and more sport specific performance based functional tests can help clinicians and coaches determine readiness to return to play (Bird & Markwick, 2016).

Personal experience from elite youth basketball, both domestic and international, has displayed on court movements that practitioners would deem sub-optimal from a biomechanical perspective but have no bearing on injury status or on court performance. This conundrum has led me to believe I need to assess movement not just for baseline measures but also to understand each player’s uniqueness.

This blend can only be achieved if we begin to combine screening and sport specific movements.

All but one existing athlete screening protocol evaluate a series of test results but provide little subsequent direction with regard to the necessary interventions (McGill et al., 2012). Effective correction of movement deficiencies and an understanding of how screening and subsequent interventions impact on performance or injury rates are unclear. McGill, et al. (2012) studied a series of tests inclusive of movement competency, speed, agility and strength.

Additionally, the National Basketball Association Combined Testing was used, and all tests compared with games statistics over a two-year period[1]. However, McGill et al. (2012) did no basketball sport specific testing other than the lane agility test that is in itself a non-reactive test and therefore less reflective of game and training agility (Kuzmitz & Adams, 2008; McGee & Burkett, 2003). Furthermore, for physiotherapists the fundamental point to screening is to identify perceived deficits in properties like strength or flexibility and use this to reduce injuries. Experience from the elite academy setting has shown that some of our athletes are able to perform to a high level on court even though their test results suggest this may not be possible. My aim in undertaking screening is that both

[1] Movement competency tests included a) Deep squat b) Hurdle step c) In-line lunge d) Shoulder mobility e) Active straight leg raise f) Trunk stability g) Rotary stability h) Standing posture i) Seated posture j) Segmental flexion from standing k) Segmental extension from standing l) Segmental lateral bend from standing m) Segmental twist from standing n) Gait o) Box lift from standing p) Coin lift from standing q) Single leg dead lift r) Single leg squat s) Torsion control t) Pelvis rock. Torso endurance; Front plank; Beiring Sorensen extension; Right and left side plank; Grip strength; Pull up repetitions; Bench press; Hip range of movement (flexion, extension, interal and external rotation). Standing long jump; Three bounds jump; Shark time; Speed get up test; Unconstrained lunge; Three minute Celtic run. NBA Combine tests- No step vertical jump; Lane agility test; Three quarter court sprint. Game statistics used – games played; minutes played; Points, Assists, Rebounds, Steals & Blocks per game.

my players and the coaches will benefit in terms of enhanced performance. To date no research conducted has attempted to correlate baseline and performance sport specific testing with basketball statistics and epidemiology over the course of a season in youth basketball.

Therefore, my experimental hypothesis for this thesis was that useful screening tests would correlate with selected game performance metrics. My experimental null hypothesis for this thesis was that useful screening tests would not correlate with selected game performance metrics

Research purpose.

The purpose of this project is to further both my and other's understanding of screening and how the refinement of this can be applied in a sport specific setting. A more focused and specific approach to the population and sport will provide a greater understanding for my practice and facilitate the on-going education of other stakeholders like coaches. More specifically, I would anticipate the impact on my practice to be direct in terms of changes to screening and testing protocols. As an example, I currently use both passive and active Range of Movement measures that once correlated to game performance measures should indicate both are not warranted and provide no additional data. One method would therefore be used. The project being applied will also serve as a step process that will lead us (Elite Academy Staff) to discuss further development of tests. Additional testing will be necessary prior to collectively arriving at a group of tests that provide us with information that relates directly to performance on court alongside our baseline data.

To progress toward a position where we can refine practice this project will apply a range of screening tests set into three groups (clinical, performance and neuromuscular/mixed) to a group of Elite Academy basketball players and ,gather data on performance statistics and injuries for this group across a full season. I will look for correlations between screening test results, game statistics and injury incidence. However, it is important that I am careful not to fall into the much-seen trap of using screening to try and predict injuries. Bahr (2016) describes this as researchers making a link between screening tests and epidemiology of the test group. However, few if any of these papers test and re-test with removal of cut-off high-risk athletes to validate the tests and then implement a RCT to test screening and outcomes related to injury. Essentially, if the screening protocol is not applied across multiple athlete groups no cut-off value can be set correctly. Setting the cut-off value too high will capture athletes not only at risk but many who are not, while to low will miss some athletes at risk. This is a key reason why protocols and numerical values in sports injury protocols are problematic when compared to other pathologies.

Comparisons will be made between similar tests to determine the most suitable for my population of Academy basketball players. A key benefit will be to provide me with clarity on which screening tests are useful thereby reducing unnecessary time in my future screening with tests that are of no importance to performance. A fundamental part of the process to begin to hone the tests clinicians and coaches should consider using to reduce time and cost of unnecessary screening tests. Refinement of screening tests will elicit changes to practice ensuring tests are used that provide information for performance as oppose to just data leading to greater efficiency.

Chapter 2 :

Review of literature.

Epidemiology

This Chapter aims to provide a review of epidemiology in basketball that enables me to understand fully the injuries sustained in the sport and how these may change with different ages and levels. The chapter will consider the movements required and physiology of basketball, essential if development of screening tests is to be applied in a truly sport specific and functional manner. A review of current screening protocol literature will set the current scene and illuminate the shortcomings, before individual tests are considered to help inform the development of screening protocols and most importantly future practice.

Epidemiology of basketball indicates there must be a better way to screen and apply strategies to prevent injuries. Those may require adaptation to suit the age, level and time interventions when applied. Although the data on types and trends of injuries across sports increases, the sports medicine community are still unable to decrease the incidence of injury (Hootman., et al, 2007; Dhillon 2012; Orchard 2016), with basketball no exception to this. The epidemiology of basketball contributes to the direction and inclusion of types of tests within a screening protocol by identifying high-risk injuries and their likelihood of occurrence. Functional test batteries described as screening protocols do not reflect evaluation of high-risk injuries in basketball and are not dynamic. Mimicking training and competition movements at the speed of the game could be a useful tool for sport specific functional testing and thus likely to be a better predictor and preventer of injury. The three elements of epidemiology, screening protocols, and training and competition movements, combine to present a problem that taken individually, each cannot solve. The inability to recognise the demands of the sport alongside current epidemiological trends and screening protocols leaves room for development of screening and testing more closely aligned to both the sport and performance outcomes.

Epidemiological studies of injury in basketball have predominantly been conducted in the United States due to its popularity and levels of participation in the sport there, with an estimated 1.75 million participants per day (Carter et al., 2011) . It is inevitable in a sport that is fast paced and involves moments of contact (Starkey, 2000), that a significant number of injuries are prevalent. During a six-year period 2000-2006 the number of basketball related injuries presenting to Emergency Departments in the US was 325,465 for 7-17 year olds with 12-17 years accounting for 81.1% of these cases (Pappas et al., 2011).

Several studies suggest the highest frequency of injury across age groups, levels, and gender, are ankle injuries. One 16-year study in the American Collegiate system reports ankle injury rate to be 26% of all injuries for both games and practices (Dick et al., 2007). Starkey (2000) in a 10-year study in the National Basketball Association finds it to be 10.9% of all injuries and 16.9% of in game injuries. A similar paper on NBA injury rates over 17 years confirms the findings that lateral ankle injuries are the most frequent accounting for 13.2% of all injuries sustained, but patellofemoral inflammation caused the most days lost due to injury at over 17.5% of all games missed, almost twice as much as lateral ankle sprain (Drakos et al., 2010). Herzog et al. (2019) season long study of the NBA found a 26 & risk of ankle injuries with an increased risk of 1.41 if a player had an ankle injury the previous season. The lack of epidemiological studies in European basketball make it difficult to compare US injury rates with those in Europe, but Leanderson, Nemeth & Eriksson (1993) found 78% of respondents had suffered an ankle sprain in the last two seasons which, may suggest European rates of ankle injuries are higher than in the US. Comparisons to the US studies should be taken with caution as Leanderson, Nemeth & Eriksson (1993) study was of 102 basketball players from Sweden Division 2. The relevance of identiying injury differences across continents lead us to try and understand what elements of game play contribute to the type and rate of injury. An element worth considering are the rule differences between NBA and FIBA that could contribute to changing risk factors. No reaserch to date has considered this as a primary research question.

In adolescents, rates of basketball related ankle injuries per year presenting to emergency departments are high. Between 2000-2006 basketball related ankle injuries accounted for 21.7% of all basketball injuries presenting at emergency departments in the US. This is similar to senior player rates (Pappas et al., 2011). Two studies have indicated that the high percentage of ankle injuries are re-injuries. A study of 164 senior men and women players in Belgium at all levels stated 53% had previous ankle injury (Cumps et al., 2007) and from an senior elite competition in Australia 73% reported previous ankle injury at recreational level and 22% at an elite level (McKay et al., 2001a; McKay et al., 2001b). Cumps et al. (2007) also listed injury risk factors that included an increased risk in offensive play, jumping compared to change of direction and the level of play. This latter point suggests the higher the level the lower the risk and higher risk for lower level. This may be indicative of physical characteristics or skill set. This may suggest not enough is being done, understood from the available resources like video analysis of injuries or sought during the rehabilitation phase before return to play. Three areas found correlate to injuries from the McKay et al. (2001a) study was re-injury had 5 times the injury risk, shoes with air cells had twice the injury risk and not stretching provided an increased injury risk of 2.6 times. Moving into the areas of shoe design and the ongoing debate on stretching are beyond the scope of this paper but, air cell shoes would provide greater cushioning but less stability. Stability, proprioception, and a player's ability to control these elements along with posture has been correlated with a significant reduction of ankle injuries by 81% in a six-year long study of Italian First Division Professional Basketball (Riva et al., 2016). Proprioception and not strength or flexibility has been linked to ankle injury risk in collegiate players (Payne et al., 1997), suggesting that the neuromuscular component of rehabilitation is the most important factor in trying to reduce reinjuries.

The knee is the second most injured musculoskeletal joint although this is different for males and females separately (Andreoli et al., 2018). Terminology for knee injuries differs from paper to paper[2] and as such it is more difficult to

[2] Acknowledgement of terminology has been made in studies that make it difficult to make direct comparisons with other research. Pappas et al, (2011) refer to injuries as knee sprain but no clear definition of which ligaments involved is given. Dick et al, (2007) describes injuries by body part and knee injuries under one category as internal derangement, one can assume this is to mean ACL injuries as this is the only specific injury alluded to in the paper. More detail is given by Starkey (2000) but the different terminology make comparisons difficult compared to other papers. Starkey (2000) uses patellofemoral complex injuries (trauma and inflammation), meniscal tear, knee contusion, general capsular sprain and knee sprain with ACL, PCL, LCL and MCL all listed.

quantify an average rate but this ranges from 3.9% of knee sprains presenting to Emergency Departments in the US for 12-17 year old boys (Pappas et al., 2011), 9.8% of combined knee internal derangement and patellar tendon injuries for NCAA males over a 16 year period (Dick et al., 2007) and, 13.8% frequency of all injuries across a 10 year study of NBA injuries (Starkey, 2000) (combined diagnosis of patellofemoral inflammation, knee sprain, knee contusion, meniscal tear and quadriceps strain). The leading cause of time loss injuries is patellofemoral complex inflammation at 11.5% based on a days missed percentage from an NBA 10 year study (Starkey, 2000).

As mentioned previously knee injuries are second most prevalent inury in basketball but, only when total inures are considered. Andreoli et al. (2018) found that when you separate foot and ankle injuries there is a higher prevalence of thigh, hip and leg injuries than foot or ankle alone at 19.3%. This percentage of hip injures is much lower in adolescents and children at 8.5%. Adreoli et al. (2018) systematic review does complicate the pattern of inures form previous long-term studies. However, it does lead us to think more carefully about injury types and prevalence the hip and thigh region a higher risk area and head and neck in double percentage figures as a total and for children and adolescents.

Although lower limb injuries are the most dominant injury area in basketball, upper limb injuries do occur. Pappas et al. (2011) found in a 6-year study of paediatric basketball injuries in the United States that finger sprains and finger fractures were more prevalent than knee injuries in both 7-11- and 12–17-year-old boys and girls. Starkey (2000) found finger sprains and dislocations were 12th

on the injury rates list (not including medical problems of gastrointestinal and upper respiratory tract infection. Epidemiology has also detailed structure where shoulder was 8th and wrist 13th, with finger 14th. Overall, the upper extremity was third behind lower extremity and general medical and accounted for 12.1% of all injuries (Starkey 2000).

It is also worth considering training load in relation to injuries here even though this is not the focus of the study. Agreed baselines for thresholds of training loads in basketball have yet to be fully established, especially when considering the different ages and levels of the sport (Conte et al., 2018). A study of one NCAA team in Division 1 looked at 10 male players across 1 season and found the Acute:Chronic Workload Ratio (ACRW) may be 1-1.5 to assist in the prevention of acute and overload injuries. However, even though weekly spike increases up to 226% were found there is, as previously suggested no baseline data or threshold to compare this to (Conte et al., 2018). A study in New Zealand monitored 13 male professional players for 1 season and found the ACWR between 1-1.49 was the optimal threshold for reducing injuries. Although this seems like a pattern two elements should be considered. Firstly, this was optimal compared to very low (<0.5), low (0.5-.99) and high (>1.5) thresholds. Secondly, even though the 1-1.49 showed lower injuries as comparisons, this ratio still had 36% of injured players (Weiss et al., 2017). Although training load has been applied to team sports, it may be that the different environment, pace of game, number of movements and substitutions mean the demands are quite different to outdoor field-based games. Much research is yet to done in this field for basketball and the different genders and levels and ages of players. Training load is only part of a very complex puzzle that is looking for the recipe in reducing injuries.

Sport specific physiology, movement and performance.

Fundamental to this professional doctorate is understanding the demands of basketball and develop appropriate testing that relate to these and relevant performance outcomes. Without a good understanding of the type, regularity speed and direction of movement, and how this is integrated to practice and game scenarios, it is difficult to see how testing can be applied with sport specificity at its core. The following section considers research around physiology and movement for basketball and how these relate to basketball performance and testing.

Physiological load has been studied previously with authors looking at different parameters. One approach to grasp the degree of intensity is to look at number of movements per minute. During game play this is widely agreed to be in the region of a basketball specific movement approximately every 2 seconds (Puente et al., 2016; Torres-Ronda et al., 2016; McInnes et al., 1995; Ben Abdelkrim et al., 2007) equating to between 997 and 1050 movements per game (Ben Abdelkrim et al., 2007; McInnes et al., 1995) . This is distributed as a greater percentage to both low and moderate intensity (30-36 % of live time) as opposed to high (8-10% of live time). Although a direct comparison between papers is difficult to quantify given the varying terminology and methods[3] (Ben Abdelkrim

[3] Terminology and parameters used to measure on court live time movements a) sprint, b) high specific movement, b) jump, c) total high intensity, d) run, e) medium specific movement f) total

et al., 2007; McInnes et al., 1995; Torres-Ronda et al., 2016) . Puente et al (2016) suggest some over estimation has occurred in previous studies that utilised time and motion video analysis compared to their use of Global Positioning System (GPS). This more objective measure showed work at the higher intensity threshold consisted of just 3% of the total volume based on running speed Puente et al 2016).

Work: rest ratios in basketball vary dependant on what the activity is. During game play this can range from 1:1 medium to high intensity movements and 1:10 for high intensity to maximal activity. These ratios equate to 15:15 seconds and 10:50 seconds respectively (Abdelkrim et al., 2010; Ben Abdelkrim et e., 2007).

Stojanovic et al. (2018) reviewed the work intensity, duration and volume and reported an average 5-6 km travelled during game play at ≥ 85% lactate threshold and a reduction in intensity in the last quarter of the game. The findings from research on the level of intensity does not mirror some research that have used Heart Rate (HR) and maximum oxygen capacity ($VO_{2\ max}$) which were found to be at the higher intensity level (Ziv & Lidor, 2009). During game play percentage of HR_{max} was between 85-91% (McInnes et al. 1995, Narazaki et al. 2009, Ben Abdelkrim, El Fazaa & El Ati 2007) , which, as Ziv & Lidor (2009) highlight seems at odds with the percentage of high intensity work during game play. This discrepancy may be due to methods used to measure the physiological and

moderate intensity g) jog, h) low specific movement, i)total low intensity, j) walk, k) stand, l) total recovery (Ben Abdelkrim, El Fazaa & El Ati 2007) .
1. Stand/walk. 2. Jog. 3. Run. 4. Stride/sprint. 5. Low shuffle. 6. Medium shuffle. 7. High shuffle. 8. Jump (McInnes et al. 1995).
1. Pick. 2. Shoot. 3. Pass. 4. Specific high. 5. Specific medium. 6. Specific low. 7. Jump. 8. Sprint. 9. Jog/run. 10. Walk. 11. Stand (Torres-Ronda et al. 2016)

intensity parameters. Partly this may be due to how appropriate or not these methods of measurement are in a high intensity intermittent activity like basketball (Cummins et al., 2013).

Oxygen consumption (VO_2) has been measured at 53% VO_{2max} for 19 year old male basketball players, and at 60% VO_{2max} (Ben Abdelkrim et al., 2007) for adults during game play suggesting high aerobic workload (Narazaki et al. 2009). Demands of game play and, how this compares to sport specific training, and manipulating on court variables like number of players versus one another and, whether full or half court is used elicits differing physiological responses (Torres-Ronda et al., 2016). Friendly games were found to produce higher cardiovascular responses. Trying to replicate this in training 5 v 5 displayed a lower cardiovascular response. Both high intensity ball drill and high intensity shuffling (lateral movement) were found in 2 v 2 and 1 v 1 training scenarios with 2 v 2 also displaying a higher percentage of physical contact (Torres-Ronda et al., 2016). These findings further reinforce the need to consider the demands of the sport and for coaches and support staff to not only move toward sport specific training but to ensure screening tests resemble the sport specific movements and demands.

Basketball physiology and on court movement correlate highly to performance in both practice and games. Without physiotherapists or other support staff having an understanding of these elements it is more difficult to design screening tests that relate to sport specific movements.

Correlation to performance is multifactorial. Considering how players physiological attributes may influence game statistics and what of those statistics measured, are most influential on game outcomes.

Research that goes beyond the game statistics alone and brings in players physical and physiological characteristics provides a further angle on game performance influences. Torres-Unda et al. (2013) considered anthropometric, physiological and maturational characteristics in both elite and non-elite 13–14-year-old male adolescent basketball players. The physical advantages of taller, heavier, and greater muscle mass found for elite players is not new or unexpected. Elite player also performed better on a range of physical tests parameters including, jump, speed and agility. Those born in the first half of the year also were found to have a greater advantage of being further developed. These physical properties correlated with points average. This we know from other research is critical for positive game performance outcomes (Garcia et al., 2014; Leicht et al., 2017; Sampaio & Janeira, 2003).

One further study considered physical attributes and game performance with findings that linked only two performance variables correlated with physical performance. Jump capacity, agility, speed, anaerobic power, and aerobic power correlated significantly with steals and assists per game (Fort-Vanmeerhaeghe et al. 2016). One key point to consider here is that Fort-Vanmeerhaeghe's study was on elite female adolescent basketball players of U16 and U18 age groups.

Notably none of the aforementioned studies found correlation to physical attributes and minutes played although this is thought to be a key factor in game statistics for individual players.

Understanding player position and its relationship between physiological demands and attributes can help coaches develop training programmes for basketball specific training aligned to player position (Sampaio et al. 2006). Guards soak up more defensive pressure and are quicker in transition compared to both centres and forwards. Abdelkrim et al (2007) found guards worked at a higher intensity and were quicker and more often sprinting and dribbling compared to centres and forwards. Centres were found to jump more due to their role and forwards shot more, walked, and stood more than both centres and guards (Köklü et al. 2011). Body types and roles will have a bearing on game statistics. For example, centres 3 pt field goal attempts and percentage may be better than guards because this is not as much part of the guard's role (Sampaio et al. 2015). Overall, studies have found that playing position is influenced by body type and physiological demands (Abdelkrim et al. 2007; Köklü et al. 2011; Sampaio et al. 2006). Playing level seems more debated in the literature with Sampaio et al., (2006) suggesting there are differences between LLB, ACB and NBA. Whereas Köklü et al. (2011) found no difference in performance and player position in Turkish Division 1 and 2. In my academy setting, for all but the tallest of players, roles and skills are much more interchangeable. Players may come into the academy with a particular role in mind but that may need to change due to the players development from a physiological, anthropometric and skill set basis. Coaches, players and parent must also consider what needs to be developed in order for a player to move to the next phase of their careers. There is much less variety in height of players which makes the development and interchangeability of players important. In the 9 years I have worked within the academy, only two players have been over 6’ 10”.

Many studies have considered the most critical game statistics employing a cluster analysis by which each cluster is defined by point differences. Multiple studies found key determinants of game statistics for performance outcomes included 2- and 3-point attempts, free throw percentage and either successful or unsuccessful free throws, defensive and offensive rebounds, blocks, fouls, assists and turnovers are all critical factors in influencing game outcomes (Garcia et al., 2014; Leicht et al., 2017; Sampaio & Janeira, 2003). Cene (2018) took a cluster approach of close games (difference <10), balanced games (difference 1—21) and unbalanced games (difference >21). In close games fouls committed, steals and true shooting percentage had a greater bearing on successful game outcomes. For balanced games the 2- and 3-point field goals along with steals and defensive rebounds were deemed critical factors. Steals and defensive rebounds are most influential in game outcomes for unbalanced games.

With the research previously mentioned, game statistics used were the number of games played across the season and not minutes played. Although Sampaio et al. (2015) found some correlation with minutes played and game performance, this was using high level NBA player data and categorising them into all-star and non-all-star performers. The different playing profiles of performers shows how playing is used in different ways at different levels. For this study all players were

U19 years of age. One other element to consider for all statistics is that minutes played does provide more opportunity the more a player is one the court, however, the game performance outcomes from the minutes are dependent on both the opposition and their fitness and fatigue. Level of opposition is difficult to adjust for and I have previously detailed in this section physical characteristics and game performance.

The study has made the obvious choice to include key scoring of 2pt and 3pt field goals and free throws made and percentage season average. Offensive and defensive rebounds season average along with season averages for assists, steal, blocked shots and total points. All these have been linked to key indicators and/or physical characteristics linked with game performance outcomes (Garcia et al., 2014; Leicht et al., 2017; Sampaio & Janeira, 2003).

Screening

There are a number of key issues with screening protocols when trying to measure performance or prevent injuries. These will be reviewed with the literature focusing on Functional Movement Screen, Movement Competency Screen, and professional experience and practice.

Screening protocols are used to address or predict specific issues surrounding injury or performance by identifying a weakness. This is very difficult to achieve, as most tests require isolated controlled movements, therefore no replication of performance based functional movements is involved. Some functional tests can correlate to performance tests but not in my experience directly to performance outcomes (how an athlete performs in competition). Screening tests are typically designed to measure a specific physical element such as balance or flexibility. Some screening tests do combine physical measures but, none to date consider how many physical attributes are used simultaneously during practice or game play. These tests are very difficult to develop as the complexity of movements make measurements harder, especially in settings where resources are limited, and multiple people need to apply the test and/or evaluate it. This is a key point to my screening protocol that I address in my professional doctorate by looking at game performance outcomes and whether screening tests correlate to them. Some tests are useful in providing asymmetry information or baseline data for comparison at a later date.

Physiotherapists use screening protocols to predict injury but often fail to understand the complexities and variables that can contribute to injury and the opposite effect of an athlete with screening identified weakness not getting injured. This flawed approach has been outlined in the introduction. In practise we must considered Bahr's (2016) paper and avoid using screening or testing to predict injuries because so many other variables may be at play (diet, sleep, illness, psychological). Screening tests should therefore be used to identify areas for improvement compared to 'normal' populations, baseline measure for comparison if a player is injured and to understand the effect, if any, on performance. What we are trying to understand is to see if screening provides greater information on performance outcomes thereby indicating specific areas of focus for athletes and coaches. An example of this may be a good performance on repeated vertical jump relating to rebounding during game play.

One of the key issues with screening for us as practitioners, is that coaches want more time with their athletes (especially in national teams) and athletes want to play the game. Testing is often not sport specific and consequently not very engaging for athletes. The academy is including more sport specific tests in the daily routine but acknowledge it is a progress that may take many years to refine. However, I am trying to move toward a more informative and inclusive screening protocol that influences the time I am given by both academy and national team coaches. This is because I enable them to see the benefits between testing and playing basketball.

Functional Movement Screen is the most known and commercially available screening tool. Functional Movement Screen is a system that is task orientated as opposed to purely clinical testing of musculoskeletal joints and muscles. Functional Movement Screen tests are multi-joint movements with specific segmental controls unlike clinical testing for baseline measures. The Functional Movement Screen consists of seven tests[4] that are designed to evaluate fundamental movement patterns (Cook et al., 2006a; Cook et al., 2006b). The Functional Movement Screen is scored on a scale of 0-3 on seven measures so that 21 is the optimal score. Score meanings are 0=pain on movement; 1= unable to complete movement +/- balance loss; 2=completion of movement with compensations; 3=normal performance. These added together will provide a composite score out of 21.

[4] Seven Functional Movement Screen tests: 1. Deep squat 2. Hurdle step 3. In-line lunge 4. Shoulder mobility 5. Active straight leg raise 6. Push up 7. Rotary stability.

The Functional Movement Screen system is not meant as a form of musculoskeletal diagnosis but as an evaluation of how the athlete moves or functions in training or competition. However, it does appear to have taken a more clinical role for some professionals applying the protocol. The score of Functional Movement Screen is correlated to the athletes' risk of injury and weaknesses from each test are used as the basis to 'correct' movement pattern discrepancies. Whilst I use this information to address athlete or even patient insufficiencies as part of a rehabilitation regimen, I do not try and predict injuries with screening protocols. As has already been established, this is very difficult to achieve especially with a tool that is not sport specific.

My ultimate goal of screening is to try and identify those at risk of injury thus putting strategies in place to prevent injury. I have already referred to Bahr (2016) paper and highlighted my applied experience that explains how difficult this is to achieve. Further evidence of this paradox follows. A screening protocol of 20 movement competency tests including Functional Movement Screen tests found no correlation with injury rates in basketball. However, it did conclude that some physical parameters appeared to link to better performance outcomes in basketball, suggesting another focus of screening can be toward performance and not just injury[5] (McGill et al., 2012) . In a study of thirty-five female collegiate athletes Functional Movement Screen was among three tests found to have poor validity in predicting lower limb injuries and had low predictive ability (Walbright et al., 2017). In an applied setting like our Academy many other variables affect

[5] Increased hip ROM, torso stiffness and lane agility linked to better performance (McGill et al., 2012).

day-to-day performance. As academy staff I am unable to control all of these variables. A recent systematic review of movement screening found 15/17 studies were using Functional Movement Screen and concluded better quality evidence was needed to fully understand if movement screening tests inform us of injury risk. The conclusion of the review is at this moment there is no correlation between sub-optimal movement and injury (Whittaker et al., 2016). The research outlined here reflects that Functional Movement Screen cannot predict or prevent injury or performance. At best it is able to identify asymmetries and movement dysfunction on very specific controlled tests that bear little resemblance to on court movement or most sport movement patterns.

Correlation between Functional Movement Screen composite scores (the sum of all the tests scores 0-3) and injuries has been found but had a lower normative value than research has shown (Kiesel et al., 2007; Chorba et al., 2010) . Research suggests average values of 15 for young active populations (Schneiders et al., 2011) and 16 for fire-fighters (Peate et al., 2007). This would suggest the normative value may be specific to the athletics population in question[6]. No difference between Functional Movement Screen composite scores of athletes injured compared to uninjured in 167 Division 1 collegiate athletes across nine sports including basketball (Warren et al., 2015) . A study of over 2000 soldiers found the Functional Movement Screen composite score was no more effective at predicting injury risk than the presence of pain and as the authors suggest could be a much more efficient method for evaluating injury risk (Alemany et al., 2017). This study supports previously mentioned studies

[6] Normative value for The Functional Movement Screen is the mean +/- SD of the seven tests.

indicating that the composite score cannot predict injury. Furthermore, Chalmers et al. (2017) found in a cohort of 237 elite junior Australian football players that injury risk bore no correlation to the Functional Movement Screen composite score of ≤14. To understand fully how broad and encompassing FMS can be, Smith et al. (2017) found 72% of participants fell under the considered normative value of 14 in 41 high school athletes. Even though more than 2/3 of participants fell under the normative score, the study found Functional Movement Screen was not able to identify balance deficits, thereby suggesting a more comprehensive and sport specific approach to testing should be employed.

Although the composite scores are poor predictors according to the evidence, they also fail to explain any detail as a composite score number. If we were to look at any athlete's composite score for The Functional Movement Screen it would not provide detailed insightful information. A more thorough investigation individually to fully interpret each test is required. To succinctly apply a number to a risk of injury is in my experience short sighted. I say this with experience of composite scores used in national team camps as they provided no value to me. Within national teams we had a scale that rated an athlete's risk of injury out of 100. Were the deficits on the Y Balance test or Yo Yo Intermittent Recovery Test Level 1? Having the detail is not only critical it is essential. Screening that I developed and oversaw at the elite academy I am based at does not use numbered systems. As a clinician I want and need to know what is happening or what the issue is with an athlete, not to try and interpret a number associated with it that has been devised so it fits to an arbitrary scale.

The Functional Movement Screen does apply 5 of the tests unilaterally to identify asymmetries between each side of the body. This can be for several reasons inclusive of weakness, dominance or compensations. These findings relating to asymmetry provide more information to injury risk than the composite score and are supported in the further research of 84 collegiate athletes (Mokha et al., 2016). However, caution should be taken as Mokha et al. (2016), did not record history of previous injury and this is the single largest risk for sustaining an injury (Orchard, 2001).

Nevertheless, correlations have been found between Functional Movement Screen composite scores and mobility of the hip (Jenkins et al., 2017; McGill et al., 2012). The correlation of hip range of motion and composite scores may be suggestive that the hip is key area to focus on or that there may be a bias in the amount of hip involvement required for the screening tests. In Functional Movement Screen the hip is involved in 5 of 7 tests. The central point here is that screening tests must relate to sport requirements. Hip mobility has been correlated with both performance and injury in previous studies (Jenkins et al., 2017; McGill et al., 2012) and suggests it could be a key area, which is why I looked at this area from both a baseline measure and functional testing during the research.

Verrall et al. (2007) looked at hip range of motion and its correlation to groin injuries in 39 Australian Rules football players. The study found that a reduction total range of motion at the hip were associated with greater risk of groin injury. The total range of motion of internal and external rotation combined risk was found to consistently relate to groin injury risk in a systematic review by Tak et el. (2016). The review also noted that separate measurement of range of motion of internal rotation abduction or extension did not correlate with groin injury risk. Additionally, adductor strain has also been associated as a higher risk of injury with decreased hip range of motion (Ibrahim et al., 2007).

Further to groin related injuries, intra-articular hip joint pathology can manifest itself across of range of presenting symptoms. These include but not restricted to sacroiliac joint pain/dysfunction, hip flexor strain and lumbar pain. These can be as a direct result if femoral Acetabular Impingement or the compensatory patterns which manifest themselves that athletes adopt to avoid pain (Hammoud eta l., 2014).

Finding correlation between whatever testing protocols are used and the movement or performance of the sport is a key driver in my development of screening within the academy. Functional Movement Screens poor relationship with postural balance tests[7] indicates that a more complete and comprehensive screening protocol should be used (Smith et al., 2017). This is due to Functional Movement Screen not being able to identify all elements that a screening protocol attempts to cover and highlight. Caution should be used in interpreting Functional Movement Screen results as they have *"limited to no relationship to athletic performance"* (Lockie et al., 2015). Lockie et al (2015) are clear that coaches

[7] Y Balance Test (YBT) and Balance Error Scoring System (BESS) and Modified Star Excursion Balance Test.

should use validated tests for dynamic stability, as they will relate more to the athletes' movements.

Athletics performance is also purportedly linked to Functional Movement Screen scores, but little evidence exists to support this claim. No significant correlation was found between Functional Movement Screen and measures of athletic performance on three core stability tests (Okada et al., 2011) . One additional study investigating possible correlations between golfers' measures of performance and Functional Movement Screen using standard performance tests like vertical jump height found no significant correlation (Parchmann & McBride, 2011). This is a key point for a sport like basketball where many game statistics indicate a need for vertical jump height.[8]

Functional and performance tests should not be considered in isolation as they have been found to measure different elements of human movement. [9] From an applied perspective this means we are not duplicating tests measuring the same movement parameter but using both to guide training protocols. An example of this in Gonzalo-Skok et al. (2015) was the increased reach distance on the modified Star Excursion Balance Test (SEBT) that correlated to poorer sprint testing performance. Understanding and applying this to my academy environment would facilitate decision-making on how I interpret the test and what training methods we apply to address performance deficits.

[8] Vertical jump height is required for rebounds, blocks and steals and therefore a measurement of performance and injury prevention relating to this is of paramount importance (Harris et al., 2013; McGill et al., 2012).
[9] Functional test were Weight -bearing dorsiflexion test and modified Star Excursion Balance Test. Performance tests were Bilateral and unilateral countermovement jump test, unilateral horizontal jump test, speed tests, 180 Change of Direction test and the V-cut test (Gonzalo-Skok 2015).

The example of Star Excursion Balance Test (SEBT) used as a direct correlation with sprint performance is a statistical outcome based on test results. This does not paint the whole picture. The correlation may have not made comparisons and asymmetries between limbs or considered the level, age, gender or position of athletes that is significant in basketball. If I am considering results in a literal sense, what the example suggests is those athletes more flexible are inferior sprinters. This provides me with more information to liaise with Strength and Conditioning coaches and ensure any deficits seen are addressed correctly with performance in mind and not just to improve test results.

Both injury resilience and competition performance were studied to see if correlation could be found to fitness and movement tests (McGill et al., 2012). The study has some similarities in to my proposed study in that it is attempting to identify performance outcomes during games that are identifiable or predictable from screening tests in basketball. McGill et al. (2012) applied a series of movement competency, strength, speed, and agility tests with the hypothesis that fitness and movement tests would predict two parameters namely performance and injury resilience. The movement competency tests were inclusive of Functional Movement Screen seven tests alongside 13 tests the authors suggest are often used to evaluate injury risk by clinicians. As an experienced clinician I would debate the term “often used” as most are not widely used and certainly not used in the process of predicting injury, not just in basketball but across other sports in which I work. Tests like segmental later bend and coin pick up are not what I would deem common for athletes. Functional Movement Screen tests showed no correlation to performance or injury resilience. Limited correlation was found between torso stiffness and hip mobility and performance, but no correlation with injury were found. This should be of no surprise, as many of these controlled tests do not replicate or test demands of sport specific movements at game pace. Only torso stiffness combined with hip range of movement and agility testing correlated with game performance markers. The study had a small cohort (14) that makes it difficult to draw conclusions, although those tests with positive correlations may warrant further testing[10] (McGill et al., 2012) .

The paper highlights the challenge of trying to predict performance or injury from screening tests but, does suggest that from a battery of tests a few correlations that I can utilise in future testing protocols to test their application. Correlation is a relationship between two or more variables but does not tell us the 'how' behind the findings. In this Professional Doctorate (PD) a change in one variable may not affect the other variable therefore suggesting no causation. Correlation in both this PD and McGill et al. (2012) does not imply causation as many other unknown influences may be at play. These are significant and include player physical characteristics, number of minutes played, the opposition and injury to name but a few.

Meeuwisse et al. (2003) outlines some of the how and injury risk factors associated with basketball. A key area highlighted is player exposure. This is in training and in games and provides a greater understanding of athlete load.

[10] Tests shown to have positive correlations to performance game statistics were a) NBA Lane Agility Test. b) Torso Stiffness. c) Hip Mobility. d) Weaker Left Grip Strength. e) Standing Long Jump (McGill et al., 2012).

Simply including minutes from games may not provide great enough understanding of not only load but also training time developing skills. Meeuwisse et al. (2003) study finds a similar pattern in that ankle and knee injuries are of highest prevalence in Canadian Men's Intercollegiate basketball, and that contact with another player is the highest mechanism. Specific mechanisms of injury for each area and type are beyond the scope of this paper but biomechanics and load are often considered contributing factors. An additional significant finding was the injury rate by court zone that found The Key which had 96 injuries recorded compared to the second highest of midcourt with only 14. The paper does state a greater number of injuries in practice but that time loss injuries are most prevalent in games (Meeuwisse et al. 2003). For the prevalent injury, Wang et al. (2006) suggests postural sway in both medial-lateral and anterior-posterior directions were a significant risk factor in ankle injuries.

The Functional Movement Screen or other similar protocols are not wholly flawed. However, I should consider the tests individually and how they best fit our athletes, sport, level, gender, and environment. Tests with good validity are available like the Star Excursion Balance Test. This has been shown effective in predicting lower limb injuries (Dallinga et al., 2012). Single leg squat provides key measures of hip muscle activation (Crossley et al., 2011) and, one of the Functional Movement Screen tests, in line lunge was shown to have an association with injury incidence (Warren et al., 2014) . However, the error of trying to formulate a protocol that can be applied to many athletes or populations based on a cumulative score is where practitioners/coaches go wrong. Rating each test on a scale and combining the scales to provide an overall score fails to provide insight to each test and how it is performed by the athlete. Practitioners/coaches should instead be trying to apply tests selected based on specificity to the athlete, sport and environment and consider the test measure itself and not a scale devised for rating. It is not just Functional Movement Screen that fails to deliver but others like Movement Competency Screen progress screening but are still not delivering the goal of performance and injury prediction.

Gamble (2013) in a rationale versus evidence paper on movement screening protocols considers the emphasis national institutions put on results of screening tests. High Performance Sport New Zealand uses the Movement Competency Screen [11] that considers fundamental movement competency and load that is applied to a task. Movement Competency Screening consists of 10 tests and 5 levels of load. As an athlete becomes more tolerant to load, less dysfunction with the screening test is identified, they are ready to progress the load level. Movement Competency Screen believes that training regimens given to athletes should not exceed the load capability the athlete can tolerate. Movement Competency Screen has become an integral part of the rehabilitation process and is used to guide clinical decisions on whether additional musculoskeletal screening is required based on a pass mark within High Performance Sport New Zealand. It has become widely incorporated and relied upon as a tool that is also used to guide progression of training for athletes in New Zealand.

[11] Movement Competency Screen (MCS) tasks consist of squat, bilateral counter movement jump, lunge and twist, bilateral broad jump to unilateral landing, single leg squat, bilateral counter movement jump to a unilateral landing, push up, explosive push up, bend and pull and finally bend and pull at speed. These are to be watched in real time or videoed before manipulating the load level that the athlete can tolerate to maintain correct performance of the task. Five load levels apply in the MCS from Level 1 to assist bodyweight mechanics in correct movement using bands and cables, Level 2 uses the athletes own body weight, Level 3 uses free weights at moderate to slow speed, Level 4 considers eccentric movement pattern and Level 5 uses movement at high velocity to consider movement patterns and competency at high speed akin to sport (Kritz, 2012).

The Movement Competency Screen appears more functional in relation to sport than Functional Movement Screen but has to date not received scrutiny within the literature of the latter. Movement Competency Screen also utilises video playback that enhances accuracy and inter-intra rater reliability (Reid et al., 2015; Milbank et al., 2016) but a negative side effect of this in an applied setting means more time spent in not just completing the screening but analysing it.

Movement Competency Screen does provide a graded approach to screening with explosive movements and counter-movements added with speed (Kritz, 2012). Movement Competency Screen protocol is moving toward the functional sport specific aspect of screening but still has some way to go to replicate training and game scenarios with objective tests and measures. One key issue with Movement Competency Screen as with other screening battery tests is its inability to predict injury risk in males and females in a military cohort (Milbank et al., 2016).

I must consider screening tests and how they relate the task to the athletics activity, as these skills are highly complex neuromuscular movements. These complex movements change a basic test like vertical jump height with the addition of a target object, an activity highly relevant to basketball (Ford et al., 2005). This element of neuromuscular training according to Harmer (2005) can also reduce the incidence of knee injuries in female athletes and suggests ankle injury may be correlated to postural sway for which neuromuscular and balance training could improve. Neuromuscular training is seen as an integrated functional sport specific method of developing key physical elements like dynamic stabilisation and incorporates more concentric and eccentric muscle contraction which, is different to a primary muscle contraction in traditional resistance training (DiStefano et al., 2013). If we move to a more sport specific mode of training Judge et al. (2003) suggest athletes gain an increase in neural drive, evidenced by increased EMG activation data. Neuromuscular training includes plyometrics, core training, technical and mechanical correction with movement training, resistance and balance. This multifaceted approach is believed to reduce injury risk and improve performance (Myer et al., 2005).

The aim from my screening tests and protocols is to identify areas that can be improved by subsequent interventions and in doing so I can prevent injury and/or improve game performance. However, as discussed previously (Bahr, 2016) this is difficult to achieve and should therefore be used as performance markers (McGill et al., 2012).

Individual tests reflecting sport specific tasks are difficult to identify (Hegedus et al., 2008; Hegedus et al., 2012; McCall et al., 2015). Compiling the tests in a protocol giving them relevance to age, gender, situation, environment, resources and sport specific scenarios with, an understanding of the physiological and physical demands are not yet tackled in the literature (Ortiz et al., 2005; Ljungqvist et al., 2009). This Professional Doctorate attempts to fill some of this by being specific with regards to the level and age of the athletes, as well as gender, and considers how tests relate to performance so we can understand better what screening tests inform us about basketball performance. A key aspect that should be reinforced is this must be replicable as the academy resources are not infinite.

Screening protocols still try to predict injury but have fallen short with none to date achieving this accolade. Some screening protocols outlined in this section have seen limited success relating to measuring correlations with game or competition performance but are nonetheless still focusing too much on fixed controlled screening tests. My experience has shown that the controlled movement tests do not reflect many elements of the environment and situation I work in and cannot help to predict injury. The screening protocols like Functional Movement Screen have provided key information around types of movements to avoid being drawn into being included in the screening protocol. Within my work with athletes at all levels, from recreational to elite and across a range of sports, controlling movement may be used as part of rehabilitation but, when we are moving to mid to late phase and return to training these tests or tasks become of much less use. From an early stage in rehabilitation, I am integrating aspects of the sport that individual athlete needs to remaster. Therefore, it is a logical step that this approach is taken into the screening tests used.

Individual screening test literature review.

Combining individual screening tests that may be physical field-based tests or clinic-based baseline tests, collectively make up a screening protocol. This literature review reflects the Professional Doctorate sport specificity by reviewing the evidence for each test. The review will include methods of application, reliability and appropriateness to my environment and situation. All Intraclass Coefficient Correlations based on 95% confidence interval in the screening literature review section will be as follows: ≤ 0.5 = poor; 0.50-0.75 = moderate; 0.75-0.90 = good; ≥ 0.90 = excellent (Koo and Li., 2016).

Postural analysis.

Screening and physiotherapeutic postural analysis is a fundamental part of my assessment as it has been linked within sport to postural adjustments habitually gained from activity (Kilinç et al., 2009) . My field based postural analysis has been biased toward traditional visual assessment due to the advantages of not needing equipment and being low cost. However, I find this to be to blunt a tool and consider it inadequate for minor postural observations, therefore considered inappropriate for this project (Iunes et al., 2009). Similarly, the visual method of plumb line also lacks quantifiable results (Bullock-Saxton, 1988), although both above methods are easily applied in the sports field setting. Goniometry has been previously used for postural measurement and assessment but has been shown to exhibit inconsistent inter-rater reliability[12] (Werner et al., 2014; Harrison et al., 1996). Several studies recommend using only one method of

[12] Werner et al (2014) found ICC (2,1) values ranging between 0.62 to 0.79 across five different raters.

measurement as methods/tools are not interchangeable (Mullaney et al., 2010; Otter et al., 2015). This Professional Doctorate will use inclinometry for our range of motion tests (ROM).

The gold standard for postural analysis is radiographic but the three drawbacks of radiation exposure, access and affordability mean I cannot use this either as part of the academy routine or for this project as I want to be able to replicate screening tests that are likely to be used in non-professional sports setting (Singla & Veqar, 2014). An alternative to this is to use photogrammetry that utilizes digital photographs taken at a set height and distance and analyse them using a postural analysis software (PAS) system. This approach is time effective, requiring only a camera and software and has been shown to be comparable to radiographic data (Ruivo et al., 2013). However, caution should be considered as the mathematical differences in different systems may yield variable results based on different height and distance settings of the camera (Furlanetto et al., 2016). One interesting development is the combination of photogrammetry and 3D modelling using the Microsoft Kinect™ (Microsoft, 2010) camera and a new Automatic Digital Biometry Analysis System (ADiBAS) postural platform to measure angles and distances. Although this tool is easily applied in the field, it is not yet considered affordable within my academy setting and has yet to be validated. All of the aforementioned reasons lead me to exclude the postural analysis from this screening protocol, as from experience it is not an accurate barometer of an athletes' performance.

Participation at European Championships as national team physiotherapist from U16 to U20 Men has allowed me to witness athletes from across Europe at different age groups. This exposure provides anecdotal evidence that posture does not have to be optimal to be a predictor of either performance or injury. Players with very significant kyphosis have gone on to win not only the championship but also MVP in Division A. It could be expected that players with suboptimal posture could be competitive, but to be considered the best player in Europe out of 288 athletes within the top division suggests posture is not impacting performance in quite the way we imagine. These observations have changed the way I look at individual characteristics and how I was taught they impact on performance. For some athletes there may be negative performance outcomes, but this is not the case for all athletes, and neither is the severity of one characteristic. Sport is multi-dimensional and should be approached that way when screening is considered.

This example shows why we cannot look at posture in isolation. Height is different to posture but trying to correlate height with an increased risk of injury is a challenging problem. Taller players tend to be involved at both ends of the court both defensive and offensive rebounding, meaning there is greater degree of contact compared to shorter guards (Vanderlei et al., 2013). Posture could relate to varus and valgus, protraction and retraction and kyphosis or lordosis. All of these elements may not be deemed optimal alignment but may be an injury risk. However, valgus of the knee does present as a higher injury risk of ACL to female athletes (Ford et al., 2003, Mehl et al., 2018). Furthermore, postural sway is again different to both height and posture. Postural sway can affect risk of ankle sprains as detailed in the epidemiology section (Riva et al., 2016). The risk of conflation between posture, postural analysis and height is significant and should be interpreted with caution.

Range of motion and baseline testing.

Measurements to determine range of motion (ROM) provide valuable information to help me diagnose joint and soft tissue restrictions and gather baseline measurements that can be used for comparison after an injury (van Trijffel et al., 2010; van de Pol et al., 2010) . Debate remains within the literature regarding whether to apply passive (movement by the therapist) or active (movement by the athlete) measurements, with one study suggesting active has more accuracy and less variability than passive measurements (Gajdosik & Bohannon, 1987). Considering this evidence factors of pain and muscle soreness may affect active results, whilst realising active movement is more functional. This minor conundrum means both active and passive testing should be used in order to fully understand what kind of test provides information in relation to performance and/or injury risk. I find that there is natural variability within range of motion (ROM) testing, therefore any change in daily or weekly measures would need to be beyond the level of variability to be considered usual (Esmaeili et al., 2018).

Furthermore, Esmaeilli et al. (2018) found that tests could not be correlated to training load (internal) if conducted 2- or 3-days post training or game in Australian rules football. This highlights the problem with daily or weekly markers and the effect that training, or games has on the change of measure, some of which is to be expected. Wiewelhove et al. (2015) found that changes in neuromuscular function, Delayed Onset muscle Soreness (DOMS), creatinkinase (CK) related to high intensity training similar that of intermittent team sport activity. However, they displayed low accuracy to be applied individually and more importantly reinforce the point that hard training affects directly, what we are measuring. Variability, therefore, is hard to adjust aganst within environments where athletes are training hard at regular times across a week.

Measurement accuracy and the validity and reliability of the test itself, is influenced by methods of measurement used, as different tools like goniometer and inclinometer yield different results (van de Pol et al., 2010; van Trijffel et al., 2010; Cools et al., 2014; Otter et al., 2015) . I will discuss optimal measurement methods within the literature for each relevant test below.

Upper limb range of motion (ROM).

For upper limb measures I intend to implement for the shoulder, are internal and external rotation. Cool et al. (2014) found excellent reliability for internal (INT) and external (EXT) rotation measures with both inclinometer and goniometer passively in supine and sitting positions. A supine position provides easier handling for the therapist, as they do not have to stabilize the scapular, the inclinometer is easier to use in this position, and has been shown to be effective in active and passive movements (MacDermid et al., 1999). The application of ROM tests is an important factor for functionality. For example, if a measure of internal or external rotation of the shoulder is taken in 0° abduction the position of the upper limb does not relate to a sport specific position on court where a basketball player has his/her arms up for long periods (Hayes et al., 2001).

In considering all above points, measures for the upper limb should consist of both passive and active internal and external rotation of the shoulder in supine and in 90° abduction using an inclinometer. Intraclass correlation coefficients (ICC) for these tests are ICC 0.98 external rotation and ICC 0.97 internal rotation for inclinometer use. The passive test was administered first to help familiarise the participant to the active movement. Separate testers (A, B, C) were used for inclinometry, goniometry and recording data respectively. Kolber & Hanney, (2012) compared goniometry and inclinometry were found to both be reliable but inclinometry was slightly stronger statistically.

Lower limb range of motion (ROM).

Lower limb ROM measures are a fundamental part of baseline screening in sport. Lower limb Range of Motion (ROM) testing has been shown in basketball to have a direct correlation to performance outcomes for the hip and for dynamic balance for ankle dorsiflexion (Hoch et al., 2011) . A systematic review of lower limb passive ROM measurement was conducted and considered 17 studies evaluating the hip, knee, ankle, and 1st metatarsal phalangeal joint. The systematic review concluded inter-rater reliability was low due to position of measurements and the use of 'end feel' to determine the end point of measurement. The 'end feel' is dependent on the amount of pressure applied and is greatly debated in physiotherapy generally and not just in sport (van Trijffel et al. 2010).

Personal experience of ‘end feel’ is that it is very subjective. Co-contraction from athletes or patients means you cannot always gain an accurate feel or get the joint end point to evaluate the full ROM, or to determine a pathology. End feel is not a method I use and in discussions with physiotherapy colleagues at university appears to still be taught as a traditional method rather being based on evidence.

Hip range of movement is fundamental to risk factors associated with hip and groin injuries. A recent study looked at 60 football players and found an association between previous hip and groin injuries and decreased hip range of movement. Hip Internal rotation was 21.1° vs 28.3° for injured and non-injured respectively. Total rotation (internal and external rotation combined) was 56.0° vs 64.5° for injured and non-injured respectively (Tak et al., 2016). This is questioned by a review study considering hip range of motion and groin pain in athletes and found no correlation between variables due to the limited Range of Motion differences found (Tak et al., 2017). Clinicians and practitioners’ perceptions are that hip range of motion does have a bearing on hip and groin pain. This conundrum of conflicting evidence and the perceptions of clinicians lead me to consider different approaches. Like the daily and weekly markers variability previously mentioned, range of motion may require a minimal amount of data to understand individual’s variability.

My academy’s time and access to players is limited beyond initial screening and injury so repeated measures are difficult to obtain. No academy data exists which we can use from one cohort to another so using ROM measures as a baseline is my main approach. Hip movement has not been correlated to injuries at the academy as I have not looked at correlations thus far. I am aware of the evidence in sports like football but, think it more of a complex picture than merely linking hip ROM and injuries. Strength of hip internal and external rotator muscles may also have a bearing on injury and are in my experience highly correlated to running related injuries.

Validity and reliability of hip ROM has been shown for bubble inclinometers and smartphone applications. Concurrent validity was measured against a Vicon nine-camera 3DMA system with smartphones ≥ 0.71 and bubble inclinometer ≥ 0.87. Reliability for smartphone and bubble inclinometer was ≥ 0.63 and ≥ 0.61 respectively. The hip was measured in different positions inclusive of passive hip flexion, abduction, abduction, internal and external rotation in supine and sitting (Charlton et al., 2015). This paper is important as it shows differences between what is clinic based compared to field based or functional positions. Only supine positions relate to functional positions on court, as the hip is in a neutral position similar to that when we are standing.

Hip positions are affected by other structures within the body. Hip flexion during a straight leg raise (SLR) is influenced by pelvic control and position (Gajdosik & Bohannon 1987; Herrington, 1998). SLR is not purely a test of hip mobility but also used as a neural and hamstring length test with pure hamstring length testing most often using active knee extension. A study comparing four methods of SLR and active and passive knee extension for hamstring length found no statistical differences between applications but noted active may indicate initial hamstring length whereas passive may display maximal length (Gajdosik et al., 1993). This active versus passive extension is indicative in most muscle length tests with passive effectively meaning the muscle is in more of a relaxed state allowing for maximal lengthening. Therefore, if studies are trying to determine causal relationships between injury and/or performance and range of motion, I suggest both measures should be taken.

McGill et al. (2012) considered a range of movement competency and physical tests which included hip flexion, extension, and internal and external rotation. The study found a link between increased hip mobility and performance outcomes in basketball. Hip flexion with the knee both flexed (r = - 0.74) and extended (r = 0.55) correlated with blocks per game. Although these findings are limited hip mobility is thought to be a key area for mobility, injuries, and performance. Gonzalo-Skok et al. (2015) found functional correlation between hip related movement and performance markers. Star Excursion Balance Test which has a great degree of hip based functional movement correlated with counter movement jump and 5, 10, 20-meter sprints. Each of these activities relate directly to on court performance in basketball.

Screening for hip and groin injuries is important as epidemiology suggests this is a body region that incurs injury at a rate of 0.18 per 1000 Athlete Exposures (AE) in men's basketball (Dick et al., 2007). However, some questions remain over the diagnosis of hip and groin related injuries and the terminology used in research makes comparisons between papers challenging (Orchard, 2015). Adductor weakness can indicate an increased risk of groin related injury (Engebretsen et al., 2010). Adductor weakness is prevalent before the injury occurs, so can be a predictive tool and continues to decrease during the injury for a further two weeks (Crow et al., 2010). The adductor squeeze test is applied by a sphygmomanometer at an optimum angle of 45° hip and flexion in supine. The athlete squeezes the pressure cuff between their knees in the supine position described previously (Delahunt et al., 2011; Nevin & Delahunt, 2014). Malliaras et al. (2016) have shown good reliability for both test re-test (≥ 0.94) and inter-tester reliability (≥ 0.83) in the position detailed previously. The adductor squeeze test is one that I have used as part of my baseline testing at the academy. It is a test that is easy to apply and more importantly is related to the subjective athlete feedback. The athlete also has concurrent feedback by way of a gauge they are watching which helps motivate them.

Ankle range of motion and in particular dorsiflexion is often used in screening tests, both passively in long sitting and loaded functionally, as in the knee to wall test. The importance of this measure cannot be underestimated as a lack of dorsiflexion has an association with patellar tendinopathy. The association is thought to be due to a change in landing mechanics and altered triceps surae eccentric loading increasing the stress and workload on the patellar tendon (Malliaras et al., 2006) . Given the epidemiology for knee injuries in basketball this measure must be taken and improved (Dick et al., 2007; Drakos et al., 2010; Pappas et al., 2011; Starkey 2000).

Having observed many types of athlete's, different sports demand a varied skill set that I would not normally consider optimal. However, if I consider the context of the sporting environment it is more understandable why athletes adopt movement patterns that may be a factor in injuries. An example of this is the work I do with runners / sprinters. This group of athletes are required to have maximal dorsiflexion in all running drills so they can maximise the minimal contact and maximal ground reaction force (GRF) that sprinting requires. Basketball movements are more varied and complex, and athletes will often display different running mechanics to runners. This can become a contributing factor to injuries particularly patellar tendon that I have seen repeatedly and is most noticeable during jump landing observations. Within the academy setting basketball players are taught the importance of dorsiflexion and this is reinforced during warm up routines and strength and conditioning sessions. It is a very difficult aspect to change on court as athletes are thinking about the next move and for rebounding, as an example it may be slower for basketball athletes to be in a fully dorsiflexed position.

Testing for the lower limb will consist of hip internal and external rotation ICC 0.90 external rotation in supine and ICC 0.77 internal rotation in supine (Charlton et al., 2015). Hip flexion with both extended knee ICC 0.97 straight leg raise Left and ICC 0.96 straight leg raise Right (Boyd, 2012). Hip flexion with flexed knee ICC 0.87 dominant leg and ICC 0.81 non-dominant leg (Hamid et al., 2013). Ankle passive and active plantar flexion ICC 0.96 active (Ness et al., 2018) ICC 0.99 passive (Russell et al., 2010) and dorsi flexion ICC 0.81-0.82 active, ICC 0.70-0.76 passive (Krause et al., 2011). Additionally, the adductor squeeze test will be applied with the hip at 45° ICC 0.92 (Delahunt et al., 2011).

Functional, dynamic and physical testing.

Weight bearing lunge test

Dynamic range of movement is often an additional measure of ROM beyond the passive and active previously detailed as it is thought to relate to functional movement (Hoch et al., 2011; Terada et al., 2014) . Functional movement is an activity, task or movement applied to mirror real world or, in our case, sport specific movements. Ankle dorsiflexion in a weight bearing position mimics contact and loading response in running and jump landing albeit in a controlled manner. Decreased ankle dorsiflexion is evidenced to be a risk factor in lower extremity injuries of patellar tendinopathy (Kibler et al., 1991; Riddle et al., 2004; Backman & Danielson, 2011). Ankle dorsiflexion below 36.5° in junior basketball players has an increased risk of patellar tendinopathy from 18.5% to 29.4% compared with 1.8% to 2.1% for players whose dorsiflexion was above 36.5° (Backman & Danielson, 2011). Further to this, a movement approximately every 2 seconds in basketball that involves the foot and ankle would suggest this a key area to evaluate for both performance and injury (Torres-Ronda et al., 2016; McInnes et al., 1995; Ben Abdelkrim et al., 2007).

One of the issues with weight bearing lung test (WBLT) for ankle dorsiflexion is the different types of measurement and different methods used to assess the range. The joint range can be measured as distance in centimetres from great toe to wall. It can also be measured with an inclinometer placed below the tibial tuberosity, or with a goniometer to measure the angle of the talocrural joint (Hoch et al., 2011; Konor et al., 2012) . Secondly, the method of measurement can change the outcome. The most common method is touching the knee to wall and gradually moving the foot back thereby increasing the range of dorsiflexion. This method can be measured with any device and allows for knee alignment to a vertical mark on the wall (Bennell et al., 1998). An alternative method is to place the test foot on a 30cm box and move the knee forward to dorsiflex the ankle. A method that is easier in execution but requires an assumed range of hip flexion that Bennell et al. (1998) tandem stance technique does not require (Cejudo et al., 2014). Both methods have good ICC [0.97-0.99 for Intra and Inter Rater reliability] (Bennell et al 2014) and [0.95-0.96] (Cejudo et al 2014). Minimal Detectable Change (MDC) values were [1.5cm] (Bennell et al. 1998), and [3.8°] (Cejudo et al, 2014). Minimal Detectable Change provides clinicians with a change parameter that is useful for assessing changes following injury where baseline testing has been conducted.

From my experience within the academy setting and with national teams Minimal Detectable Change (MDC) can potentially provide valuable data. This is however contentious between national team medical staff as it is thought we are not able to gather enough data to tell us what the MDC is for each individual. How much data is needed to interpret measures appropriately is also not yet agreed upon. One of the arguments against this is that ankle range of motion will be reduced following a hard training session, but this is a normal response for the level of athlete we work with and an expectation. The 'morning markers' as they are called do not account for this, so after discussions with coaching staff and players they are not applied with national teams I work in. For the academies they could be a useful tool but due to resources and the adage of time equals money it is not feasible for me or staff to monitor these reliably every day. I would like our athletes to be at a point where they can manage this themselves, but the reality is they are not yet reliable in some tasks and may provide a wrong or made up measure. This evaluation of commitment some of my athletes have has been evidenced by the lacklustre and inconsistent athlete gathered loading data that we possess. As a group of academy staff, we are unable to provide any load related guidance due to lack of data for all our athletes. I have no reason to believe this would change for any other data gathering exercise even if the athletes understood the benefit to them.

Based on the review above, maximal functionality in testing should use an inclinometer [ICC 0.98] and tape measure [ICC 0.98], (Bennell et al., 1998; Konor et al., 2012) as this is deemed more accurate than a goniometer. The weight bearing lunge test (WBLT) is validated and correlated with reference standard 2D motion capture analysis when used with an inclinometer (Hall & Docherty, 2017) and evidenced to have good intra [ICC 0.88-degree measurement and 0.93 distance measurement] and inter-rater reliability regardless of whether the measure is in degrees or centimetres (Powden et al., 2015).

Table 2.1 Range of Motion.

Study	Outcome measure	Mean ± SD	Mean difference to reference standard	ICC
Hall & Docherty, 2017	2D Motion capture (°) Reference standard	27 ± 6		
Hall & Docherty, 2017	Angle at 15cm below tibial tuberosity (°)	44.9 ± 5.5	17.9 ± 4.0	
Hall & Docherty, 2017	Angle at Tibial Tuberosity (°)	39 ± 4.6	12.0 ± 4.3	
Hall & Docherty ,2017	Maximum lunge distance (cm)	10.3 ± 3.0	16.7 ± 4.3	
Powden, Hoch & Hoch, 2015	Inter-Clinician reliability			0.65-0.99
Powden, Hoch & Hoch, 2015	Intra-Clinician reliability			0.65-0.99

Reliability and correlation to reference standards for the different ways applied to measuring Weight Bearing lunge Test.

Single leg neuromuscular control

Neuromuscular control and balance tasks are fundamental requirements of many athletics movements and through analysis using motion capture video have been shown to detect knee valgus movements associated with anterior cruciate ligament injury (Munro et al.,2012; Räisänen et al., 2014) . Furthermore related functional athletic movements including cutting and running tasks have also been shown to correlate to knee valgus, hip internal rotation and the degree of knee flexion (Alenezi et al., 2014), although this is debated with wider assumptions only being applicable to female athletes for knee valgus (Atkin et al., 2014).

Qualitative Assessment Single Leg Squat (QASLS)

One common test for neuromuscular control and balance is the single leg squat (SLS) and, has been shown through Agreement Coefficient (AC1) to be reliable for both inter (AC1: 0.37-0.61) and intra-rater reliability (AC1: 0.60-0.78) (Whatman et al., 2012; Whatman et al., 2013a; Whatman et al., 2013b) . Additional studies have found SLS performance is directly linked to improved hip abductor activation. Hip abductor muscles have been shown to be quicker to activate on good compared to poor SLS performance (Crossley et al., 2011). Anterior Gluteus Medius activation was -46ms for good performers and 106ms for poor performers. Posterior Gluteus Medius was -23ms for good performers and 92 for poor performers (negative relates to activation before foot contact, positive relates to activation after foot contact) (Crossley et al 2011). SLS is deemed reliable compared to 2D motion capture video both within day (ICC 0.59-0.88) and between days (ICC 0.72-0.91) (Munro et al., 2012) . In a study inclusive of young basketball players SLS frontal plane knee projection angles calculated using 2D video analysis showed a greater likelihood of lower extremity injury but was not deemed sensitive enough to be used as an injury prevention or risk-screening tool (Räisänen et al., 2018). The combination of hip internal rotation and adduction due to both abductor muscle weakness and poor neuromuscular control contribute to patellofemoral pain and non-contact ACL injuries. The incidence is higher in females with 4 female and 2 males out of 277 athletes sustaining an ACL injury (Zazulak et al. 2007).

A Qualitative Assessment of Single Leg Squat (QASLS) has been developed and has inter and intra rater reliability[13] and criterion validity compared to 3D motion capture (Almangoush et al., 2014; Dawson & Herrington, 2015; Herrington & Munro, 2014) . QASLS considers arm strategy, trunk alignment, pelvic plane, thigh motion, knee position and steady stance. These parameters have a 1 or 0 score with 10 being the worse score.

The reliability and practical application of this widely used test leads me to conclude that I will use it in my field-based testing. My experience with the QASLS

[13] Kappa value k=0.89-1.00 Intra-rater (Almangoush, Herrington & Jones 2014), Kappa value k=0.97 (Herrington & Munro 2014).

is that it has strong correlation with manual muscle testing for hip abductors and anecdotally a strong link between poor performance on the QASLS and ankle injuries. This means that clinically, when testing for hip abductor strength (manual) weakness on the testing often sees an athlete's inability to control knee valgus (Dawson & Herrington 2015; Suzuki et al., 2015).

Star Excursion Balance Test (SEBT) / Y Balance Test

Balance has previously been linked to risk of injury (Hegedus et al., 2015; Gribble et al., 2012) . The often-used static postural testing does not replicate functional dynamic movement and should be predominantly of use for baseline data only (Olmsted et al., 2002). Predominantly meaning most but not all baseline clinic-based measures are controlled specific movements whereas functional movement is complex uncontrolled movement. One field test of balance requiring minimal equipment has been well researched and developed to measure neuromuscular control and balance is the Star Excursion Balance Test (SEBT). The SEBT has been shown to have good inter and intra-rater reliability[14] (Plisky et al., 2006; Kinzey & Armstrong, 1998; Hertel, Miller et al., 2010). The SEBT demands multiple joint actions akin to more functional movements of dorsiflexion, knee flexion, hip flexion as well as balance, strength, and neuromuscular control (Olmsted et al., 2002). The authors noted that it was representative of dynamic postural balance and helped to identify dynamic balance deficiency, whilst also being useful as a training tool to address dynamic balance and ankle instability (Gribble et al., 2012) .

[14] ICC 0.84 Anterior reach, ICC 0.82 Posteromedial reach and ICC 0.87 Posterolateral reach (Plisky et al 2006).

Hegedus et al. (2015) completed a systematic review on lower limb screening tests and concluded the SEBT was the only test showing good correlation with lower limb injury risk three-fold with less than 94%^ of reach distance compared to the contralateral limb. Methodological quality for SEBT was good and only poor to good for medial hop and lateral hop. All other lower limb tests were deemed as having poor methodological quality and included the sprint test: 40 yards; shuttle run; vertical jump; one leg hop for distance; three hops; triple crossover hop for distance; 6-meter timed hop; 6-meter timed crossover hop; hexagon hop; medial hop; lateral hop; T-agility and multistage fitness. Hegedus et al. (2015) highlights poor methodological quality due to only one measure of reliability taken, a lack of reporting on minimally important change (MIC) and minimal detectable change (MDC) and criterion validity showed the majority of tests were not able to predict injury. The review shows how ineffective tests are at correlating to injury risk but are from a single leg test perspective more closely related to functional sport specific movement. The review did not consider the previously mentioned tests and performance outcomes. What Hegedus et al. (2015) did state is the lack of athletes used in testing. All my participants will be academy athletes, as I relate all testing to my specific environment.

SEBT is essentially a single leg stance test where the tester is required to stand on one leg and reach out toward eight points of the compass with the other leg. The reach distance is measured and used to compare contralateral and as a baseline. Plisky et al. (2006) found that a reach difference of >4cm from the limbs correlated with an increase in injury risk by X 2.5. The development of the test over time has led to less time consuming trials for familiarization and reduced the number of directions to reach as there are a high number of correlations between reach directions that has led to the development of the Y balance test (Gribble et al., 2012; Plisky et al., 2006) . Y balance test has shown to have good reliability and uses the anterior; posterolateral and posteromedial reach directions of the SEBT reducing test time significantly (Plisky et al., 2006, Shaffer et al., 2013). Literature has highlighted some challenges with the test, most notably the possibility that leg length may influence results but this has been normalized for both the SEBT and Y test by converting the result to a percentage (*stance leg length ÷ reach distance* X 100) (Gribble et al.,2012; Plisky et al., 2006; Shaffer et al., 2013) . The number of attempts in each direction to improve reliability is nine (six trials and three measured attempts) with the average of the three measured attempts being recorded (Linek et al., 2017). From my experience within my academy and in a national team environment the protocol is time consuming and so a reasonable compromise is to utilise the standard three attempts and take the average with one familiarisation trial. The measure can then be converted to a percentage. Although this is not the same as the nine-trial method, I have to find a way I can apply tests with repeated athletes in a constrained time-frame.

The Y balance test has been validated and can be applied professionally in the field. It requires minimal equipment and the reduced time compared to the full SEBT makes it more accessible to practitioners and athletes at all levels. The Y balance will be used for testing dynamic balance in this study (ICC 0.82-0.87) with normalization for leg length applied (ICC 0.99) (Plisky et al. 2006).

Secondary to this dorsiflexion is a measure to be taken both passively and through weight bearing lunge test so that any significant differences will be analysed (ICC 0.65-0.99) (Hoch et al., 2011) . These are both tests that are used daily within the academy clinic with athletes across different sports as I have baseline data to compare post injury.

Jumps/Reactive Strength Index

Vertical Jump

Vertical jump height is a key component in basketball required for sport specific movements and technical skills like rebounding, lay-ups, dunking and intercepting passes. The Professional Doctorate is focusing on the practicality and functionality of the sport and therefore I am looking to test both double and single leg jumps with different parameters. Allowing an arm swing improves vertical jump height and coupled with a countermovement is more functional except in circumstances when repeated jumps negate the ability to utilise the arms like rebounding in basketball (Walsh et al., 2007). Countermovement jumps are multi-joint explosive lower limb movements and, have been shown to be the most reliable and valid measure of jump type [ICC 0.98] (Markovic et al., 2004). Furthermore, evidence has suggested a target object changes not only the jump height, but also the jump and landing mechanics (Ford et al., 2005). This is paramount to understand individual characteristics of jump biomechanics with target objects, as this is sport specific and may guide future individual training paradigms. Within an academy setting of players aged 16-18 greater adaptation to plyometric training resulting in increased vertical jump height is noticed compared to athletes aged from 13 up to 16 years. This biological factor and training intensity, duration, and volume, must be considered to enable coaches to effectively train for optimal outcomes. Understanding that pre and post Peak Height Velocity (PHV) periods are rewarded with better vertical jump outcomes is important when knowing the training needs of athletes, periods of growth and adaptation, and how findings are interpreted (Moran et al., 2017). A greater understanding of how I can use and interpret evidence and testing is just as important as selecting the correct test and administering it accurately. Both Ford et al. (2005) and Moran et al. (2017) highlight this from different perspectives. Whilst Moran et al. (2017) takes a developmental approach looking at maturation and the effects on vertical jump height through phases, Ford et al. (2005) acknowledges increased plyometric training improves vertical jumps height as does an extrinsic motivator or target like a ball. I must consider how I use the information from research and combine it with application in my environment. Inclusion of measurement combinations to help determine PHV are being implemented at our academy. This approach is applied in the non-invasive method described by Mirwald et al. (2002) that considers standing and sitting height, weight, stature, and date of birth alongside test date. Moreover, PHV affects physical and technical performance. Guimarães et al. (2019) found that adolescent athletes who mature earlier are taller, heavier, and possessed greater strength, speed and agility. The early matures remained quicker, more agile, and stronger even when height, age and body was controlled. Understanding the impact of growth stages in our athletes is earlier and at a slightly younger age than with our academy elite group. However, a conscious consideration should be noted for those who are especially late o. the develop cycle.

My screening protocol will consider double and single leg vertical counter movement jump height using arms [ICC 0.93] (Slinde et al., 2008), in three different environment situations all using the Just Jump System (Probiotics, Huntsville, AL). Changes to the stimulus and environment move testing toward a more sport specific position and is in line with both my and academy ethos. The Just Jump System has been shown to have excellent validity [ICC 0.92 mean] (Nuzzo et al., 2011) and correlation [Pearson r = 0.967] to a criterion reference point of a 3-camera motion analysis system (Leard et al., 2007). Research suggests the Just Jump System overestimates jump height and can be corrected with an equation[15] but the consistency of use will make our data comparable to deem this unnecessary (McMahon et al., 2016). This simple method of mechanical lower limb power has long been established (Bosco et al., 1983) and is found to be a reliable [r = 0.95] tool so long as assessment methods remain consistent with the same apparatus (Garcia-Lopez et al., 2005).

Ground contact time

Ground contact time (GCT) provides a direct correlation to on court basketball performance, in particular rebounds and put backs, and aiding team sports like basketball by enhancing the athlete's ability to leave the ground quickly and repeatedly in an unpredictable environment. Longer ground contact times have been shown to correlate to an increase in VO2 indicating poorer efficiency (Ball et al., 2010) and a decrease in speed (Nummela et al., 2007) . Furthermore, GCT is an essential component of quickness in sport be that repeated jumps or foot speed in agility-based movements. Wong et al., (2012) looked at single leg

[15] Correction equation: Criterion jump height = (0.8747 X alternative jump height) – 0.0666.

hopping and lateral footwork for speed. The study found longer GCT with hop with higher values in both peak force and the rate pf peak force. Lateral speed footwork had lower GCT as step frequency reduces contact time allowing for quicker movement of limbs. Therefore, if we consider agility-based movements in basketball and the more plyometric based activity required for repeated jumping the importance of GCT is evident. Cutting and changing direction (COD) places a higher GCT for this agility task but is due to the braking required at speed, this is different to the quick feet lateral speed tests. These studies are only considering the physical part of GCT measures and the decision-making cognitive element which has a significant impact on game performance outcomes should not be forgotten.

Sport specificity is an important determinant in understanding how physical measures relate to game play. Muira et al., (2010) looked at single leg lay-up shot and both single and double leg countermovement jump in 19 basketball players aged 19.6 yrs. The study found the lay-up shot correlated with the single leg countermovement task more so than the double for height but the opposite for ground contact time. This is thought to be due to the horizontal aspect the lay-up shot which is thought to be similar to the long jump ground contact time (Miura et al. 2010).

Repeated jump tests both loaded and unloaded were part of a review by Natera et al. (2020) but found poor methodology and comparison between studies. The Bosco 60's jump protocol has been widely used as it produces stretch shortening cycles that relate to sport but have yet to find a defined and agreed protocol for either testing or training. Research has looked into a more functional sport specific approach to repeated performance by combining repeated sprints and jumps. Buchheit (2010) found sprint running performance decreased when adding a jump during the rest phase, that shuttle sprinting impaired jump performance compared to straight line sprints and most importantly that repeated jumps and sprints have different performance qualities that are not significantly correlated. There is however a greater demand physiologically when jumps are included in repeated sprints when considering O_2 uptake and blood lactate. Considering this research maintaining separation for this study looking at direct correlations is key. Furthermore, the setting does not have capacity or equipment to test 60 seconds of jump as in the Bosco protocol (Bosco et al. 1983).

Therefore ground contact time will be measured by a four consecutive jump test using the Just Jump System (Probiotics, Huntsville, AL) that calculates average ground contact time (ms), power factor and average height (cm) (ICC 0.96) (McMahon et al., 2016). Ground contact time will be taken alongside average jump height on repeated jumping X 4.

Reactive strength index modified (RSI mod)

Reactive Strength Index is thought to evaluate the effectiveness of the Stretch Shortening Cycle (SSC) performance that is a concentric and eccentric rapid movement akin to vertical jumping and drop jumping (Flanagan & Comyns, 2008). It is suggested to be important as a relative measure for change of direction, speed and agility, all components required in basketball (Young et al., 2015; Young et al., 2017). Reactive strength index was originally developed using drop jump techniques (Young, 1995). Its application and relativity to physical attributes other than explosive strength requires a greater understanding of sport specific needs. Understanding how to test these is essential, as the original drop jump reactive strength index incremental measure does not depict the ground contact time seen in sporting activities.

Reactive Strength Index has been proven to be a valid and reliable tool but some researchers differ in their views on its reliability for measuring maximal and sub maximal jumping (Lloyd et al., 2009; Suchomel et al., 2015). Differences shown between both contact time and jump height, key factors in measuring Reactive Strength Index, suggest adolescent athletes are not neurophysiologically developed adequately to cope with maximal hopping compared to sub-maximal hopping. The increase in force applied and subsequent load requires athletes to tolerate compressive load whilst maintaining sound biomechanics to repeat a jump task (Lloyd et al. ,2009). My experience coupled with the research on maturation and counter movement jumps in the previous Vertical Jump section seem to correlate to athlete capability. The greater challenge for me and colleagues is to understand where athletes are in their individual growth cycle.

Evidence suggests that Reactive Strength Index performance is dependent on sport/activity and will be different for player, position, and gender (Ebben & Petushek, 2010, Suchomel et al., 2015). Research conducted in 2015 suggests one trial will help to standardise the method with strict instructions and lead to high reliability of Reactive Strength Index measures (Markwick et al., 2015).

Reactive Strength Index is measured by calculating the jump height divided by ground contact time (Lloyd et al., 2009). As a measure for comparison Reactive Strength Index results < 0.25 relate to fast SSC and > 0.25 slow SSC. Using these parameters as guidance can help coaching and rehabilitation staffs develop appropriate training programmes to enhance performance (Schmidtbleicher, 1992). Reactive Strength Index data will be calculated during the ground contact time jump test with clear instructions on maximal force plus minimal contact time using high and fast. Using the Just Jump System (Probiotics, Huntsville, AL) height is substituted by the flight time that is highly correlated with height (Garcia-Lopez et al., 2013) and time to take off with ground contact time (GCT) (Suchomel et al., 2015). The equation is Flight or Height / Ground Contact Time and referred to as Reactive Strength Index modified (RSI mod) [ICC 0.96] (Suchomel et al., 2015).

Speed tests – linear

Basketball requires repeated short explosive movements in both linear and multiple directions as evidenced in Chapter 2.1.3 Sport specific physiology, movement and performance in this paper . Significant differences have been shown between elite and sub-elite players on both mean duration and mean distance on sprint performance with the latter being <50% lower for elite compared to sub elite (Scanlan et al., 2011). Another notable point from this study shows that distances covered in play are shorter than the field tests which are typically 10m, 20m, 30m sprints. In contrast the time motion studies previously cited in this paper in Chapter 2.1.3 Sport specific physiology, movement and performance, show elite players sprint for distances up to 3.92 m and 9.48 m for sub-elite. This suggests I need shorter tests of 5m but these tests have not yet been validated. From courtside observations those players more experienced with a better comprehension of the game are more efficient in their position and where they need to be. This would explain the difference between elite and sub elite basketball players. One study looking at 14 adolescent football players aged 16.7 years considered the comparison between sprint performance and sprint speed during game play. The paper found that the quicker players had faster running speeds during game play than slower comparative players, and found that different playing positions applied a varied percentage of maximal sprint effort in game play. This finding suggests players maximal springing speed and playing position influence peak game speed (Mendez-Villanueva et al., 2011).

From a static start athlete in team sports reach maximum speed at approximately 36m (Delecluse et al., 1995) and at 27m from a flying or rolling start (Coleman & Dupler, 2004). Therefore, basketball players will not reach maximum speed during training or game play due to the court size. To understand the relationships of performance and physical tests I need to see if there is relevance to distances shorter and longer than typical on court movement and court dimensions. Therefore, 5m, 10m and 20m tests for linear speed and determining their correlation with other performance outcomes should be considered. These tests should be conducted on a basketball court so the same testing, game and training environment, and more importantly, surface is utilised. The justification for this approach is to understand the relationship of screening and testing to game performance outcomes that in this study supersedes the physiological performance for each athlete. Work with elite youth basketball has provided enough experiential evidence that playing positions will have a bearing on results and that playing position itself is influenced by the body type. Some performance outcomes have been seen in my academy team to relate to agility and acceleration ability of individual athletes.

Accuracy of sprints is critical especially as I intend to introduce a shorter 5m distance. Within my academy setting electronic timing gates (Smart Speed, Fusion Sport, Brisbane, Australia) are used across sports, particularly the athletics group. These gates will be employed during the study and used over the 5m, 10m and 20m distances, as these are valid and reliable [ICC Intra 5m 0.88, 10m 0.96, 20m 0.99] (Sayers, 2015). Electronic timing gates have been found to have better reliability and validity compared to handheld stopwatch (Hetzler et al., 2008; Mayhew et al., 2010). Each athlete will complete 3 trials of each test and will start 0.3m behind the timing gates to standardise the test as different start positions have been shown to produce varied results (Altmann et al., 2015). The height of timing gates will be set to 1m although it is recognised athlete height particularly in basketball may still affect this further (Cronin & Templeton, 2008). One of the key reasons timing gates of this nature work well is the light system that, provides a stimulus for the athlete and thus a higher degree of motivation is apparent.

Reactive and non-reactive agility

Agility is defined as a fast-whole body movement at varying speed in response to an external stimulus (Sheppard & Young, 2006). The physical element is clear in this definition, but the external stimulus is suggestive of a cognitive and perceptual element (Sheppard & Young, 2006). Agility in sport has traditionally been measured through non-reactive predictable tests but an athlete's ability to process complex multifaceted information at speed in a game situation suggests greater resemblance to the sporting environment during field tests, which would be more applied and beneficial (Spiteri et al., 2015). The cognitive or perceptive ability needs to be understood and separated from the speed element so coaches can accurately target training strategies for each athlete (Scanlan et al., 2014; Spasic et al., 2015; Zemková & Hamar, 2013; Zemková & Hamar 2014; Zemkova et al., 2013; Sekulic et al., 2014). Given the high physiological demand and constant task change in modern basketball (Ben Abdelkrim et al., 2007; Torres-Ronda et al., 2016; McInnes et al., 1995; Scanlan et al., 2011) athletes ability to react to a stimulus through muscle pre-activation might protect them from injury, by enabling greater rate of force development and associated muscular stiffness. Athletes who are more experienced and performing at a higher level anticipate on court movements quicker and prepare their body through muscle activation or contraction via the neurological system. The quicker decision-making produces increased physical performance outcomes (Bencke & Zebis, 2011; Spiteri et al., 2015). Players deemed of a higher level by academy staff do have a greater level of neuromuscular control and appear quicker on court even though some pre-season tests results may not indicate they are in the best physical shape.

A recent systematic review found that reaction time and accuracy alongside foot placement were related to agility performance. The review was not able to conclude if strength is a contributing factor but does suggest a lower level of reliability for younger athletes (Paul et al., 2016). Working with elite youth basketball players it may be the predictive nature of some agility tests I currently use facilitate a predictive pattern not only of direction for the athlete to move but also what position to shape their body for optimal performance. During games and practice sessions this is not possible due to the unpredictable nature of basketball. It is a key factor that my project should move testing to be more reflective of sport specific movements and scenarios.

However, it should be acknowledged that field-based testing may not always have the same degree of accuracy as a laboratory environment but should have more applied relevance to the sport. Paul et al. (2016) systematic review does highlight sport specificity as a shortcoming from existing research. Sekulic et al. (2014) used four directions as possible options in an attempt to address the deficiencies of the classic Y shaped agility reactive tests. Whilst it is recognised this is a step in the right direction the four-gate option are all in front of the athlete. It therefore does not add perceptual and visual challenges that athletes experience on court from the periphery of their sight and indeed behind them. Furthermore, there are specific movements in basketball like the side-shuffle that are not tested, with all movement options in front. What I am trying to achieve is agility testing that encompasses the perceptual and cognitive elements alongside the sport specific movements. In reality I know the perceptual element is limited as we have no opposition to use during testing, but I need to ensure the cognitive aspect of agility is included as I can see on court decision making in some players is notably slow.

Sekulic et al., (2013) considered physical parameters in a variety of agility tests in both male and females. Participants were 32 male and 31 female collegiate athletes who completed a series of agility tests including the T-test, Zig Zag test, 20 yard test, forward / backward test and T180 test. They also had power, speed and balance measured which were then correlated with the agility tests. Findings from the study were that both power and speed relate to agility performance in female athletes, but not males. However, balance was found to be a predictor for agility in males. The authors suggest these findings may be due to a lack of specificity in the physical test's parameters. This gender difference of performance determinants on agility performance has been seen in further studies. Delextrat et al., (2015) found sprint performance influenced agility performance in females, and unilateral jump performance and body mass were the influencing factors for males. The agility tests developed in this study was novel and considered to incorporate both offensive and defensive movements. However, the agility test was planned and as such takes away the unpredictable nature of game or training found on court.

Paul, Gabbett & Nassis (2016) make the point that agility testing should be made more sport specific but to understand what the objective is prior to developing a test is essential. Understanding the differences between field, lab and sport specific testing is critical in the applied field setting. Research comparing timing gates and motion capture and controlled and uncontrolled arm movement during an agility test have highlighted some differences (Whiting et al., 2013). The authors refer to arm movement as non-performance related movement but acknowledge in discussion that this is an unnatural way to move. Whitting et al.

(2013) also states that timing gates level of precision drops with uncontrolled movement (i.e. arm movement) compared to motion capture. Whittng et al. (2013) paper provides a good example of affordability of a system and whether a test should be controlled or applied in a field-based sport specific way. To develop screening and testing in my academy both affordability and sport specificity need to be achieved. Affordability is obvious in that I must practice within the resources at my disposal and introducing greater sport specificity will enable coaches to relate testing to practice and games.

Specificity or relevant and appropriateness of testing to the sport is essential to gain useful data and has been well evidenced in reactive agility tests conducted for different sports. These have shown sports require specific test protocols within their environment and can therefore best tailor this to player position and passages of play e.g., defence (Spasic et al., 2015; Zemková & Hamar, 2013). Ensuring the correct distance between points of contact can both elicit different qualities in agility and differentiate between player positions depending on what is targeted (Zemková & Hamar, 2013).

My experience with GB national teams is that the national governing body does not have the resources to test reactive and non-reactive agility so tends to utilise predictable tests. This is acceptable as a comparison across time but as staff change so does the testing criteria. Additionally, Sport Science & Medicine (SSM) staff cannot agree what testing should be used for agility, although clear agreement is found on the absolute need for it, as agility is a key attribute of the basketball player. The gathering of data is a driver for SSM departmental leads so a level of objectivity in measurement is required although at a national level this data is not utilised to inform and improve practice. Within an academy setting I am able to utilise university-based equipment that provides accuracy. However, research does highlight some limits to using a light stimulus even though it may be reliable as this is one part of the cognitive processing procedure. Initial detection and reaction to a light stimulus is a relatively simple process compared to the fast paced, dynamic visuo-motor and perceptual skill required during a basketball game (Abernethy & Russell, 1987). The alternative is to accept that human driven interaction as a stimulus may decrease reliability and will almost certainly mean there is variation in testing (Paul et al., 2016).

Considering the challenges and requirements I need for agility testing will combine objectivity and stimulus with multi-directional movement for both reactive and non-reactive tests. Electronic timing gates (Smart Speed, Fusion Sport, Brisbane, Australia) will be used to test non-reactive and reactive agility. This system has been shown to be reliable in linear speed (Sayers, 2015) and agility tests [CV 1.6%] (Oliver & Meyers, 2009). Four gates will be set at each corner of an 8 m square and participants will sprint through each gate 4 times meaning a total of 16 gates [ICC 0.80] (Stewart et al. 2019). This will be either in a pre-planned route for non-reactive or random for reactive. The random sequence will be triggered by light stimulus.

My decision to use 8m instead of 5m relates more closely to the average distance covered from in game movements, ensuring adequate space is provided between left and right borders (Scanlan et al., 2011; Scanlan et al., 2014) . This is not an insignificant point when I think of the athletes I have at the academy, who range from 180cm to 212cm in height and will have different stride and leg length. Participants will complete one familiarisation trial and one test trial for both reactive and non-reactive agility test that will be calculated as a ratio for Perceptual & Reactive Capacities (P&RC) that provides a framework to determine an athletes optimal agility (Spasic et al., 2014; Sekulic et al., 2015). Moreover, this information is critical within the sport setting as the perceptual and reactive abilities (PRA) of athletes allow coaches to tailor training to target areas of need and determine the percentage of how much an athlete's agility is maximized in game play situations, by analysing the difference between pure agility and reactive agility (Sekulic et al., 2014). Evidence suggests sport specific tasks require sport specific tests to elicit the physical variance seen in athletes, even though some movements appear similar or are conducted in a linear environment. Using reactive and non-reactive tests over the same course allow me to better understand these natural variances (Cavar et al., 2013).

T-test

In addition to the reactive and non-reactive tests set out previously, the Agility T-Test will be used as a common method to test agility and is part of my wider academy compulsory testing programme. Agility T-test has strengths in that it combines basketball side shuffle movements, and weakness, in that it is a controlled and predictable test. The use of an additional agility test allows data to be used as part of our analysis and will allow a further comparison against the new reactive and non-reactive tests, as well as performance outcomes and injuries. The Agility T-Test is a well-used and standard agility test used widely in basketball (Delextrat & Cohen, 2008) with good reliability [ICC 0.82] (Munro & Herrington, 2011) across sports through many studies [ICC 0.98] (Sekulic et al., 2017; Pauole et al., 2000). The original T-test demands four directions of movement from the athlete in as fast a time as possible. This tests forwards, backwards and left and right movement. Research has suggested the T-Test can be used as a measure of leg speed, leg power and agility, with leg speed found to have strongest Intercorrelation coefficients [ICC 0.73 Females, 0.55 Males] (Pauole et al., 2000). Agility T-Test is a letter T shape with each line 10 yards long and requires a forward, left, right and backward running action and touch the base of each cone throughout. A checklist for this test procedure from original article (Semenick, 1990) will form the basis for the test.

Torso Strength Endurance

Core control can be defined as the ability to control the position and movement of the trunk over the pelvis thereby facilitating the optimisation of energy from the extremities to torso and back to the extremities (Kibler et al., 2006) . Isometric core training has traditionally been employed in rehabilitation and its efficacy is thought to relate to posture and how it influences load tolerance and thus injury (McGill et al., 1999a; McGill et al., 2003; McGill et al., 2010; McGill, 2010) . This in simple language means posture which is deemed sub-optimal (optimal posture is also debated) is less able to tolerate load imposed upon the trunk and spine. This is in a large part thought to be due to weak or poor activation of the core musculature. However, core muscle contraction does not enable functional movement when isometric. Isometric contraction has predominantly been taught to stabilise the spine prior to moving toward more functional based tasks. The step process of stabilisation and isometric activation of trunk muscles that activate slower is known as a timing delay. The timing delay is thought to be a contributing factor to low back pain and injuries and is ideally addressed alongside training and/or rehabilitation. Within the academy the ability to control the lumbar spine through core muscle activation is taught across all sports and has a greater requirement in sports like athletics and sprinting as a lack of control allows the pelvis to tilt, which in turn affects the length of the hamstring. Within the academy trunk activation is a key part of injury prevention and rehabilitation for low back pain and is worked on to optimise functional movement.

More sport specific related testing is essential if injury risk factors and performance are to be identified. Static core stability endurance tests are thought to have little transfer to the sporting environment and sport specific skills (Parkhouse & Ball, 2011). Finding the correct test to measure core stability knowing this has a direct correlation to low back pain in basketball is essential (Leetun et al., 2004). Two key elements to consider are that core musculature does more than activate the core as in trunk flexion. The core musculature assists in hip flexion when hip flexors are too weak for the task or fatigued. Couple the hip related assistance to the role of quadratus lumborum that helps pelvic elevation, enabling more efficient leg swing, one can see the relevance of core in a functional setting (McGill, 2010). Secondly, core muscle activation studies have shown the complexity of torso muscle activation. Studies are suggestive of either strength or endurance bias, suggesting one test is inadequate to cater for both elements (Cowley et al., 2009; Ekstrom et al., 2007) .

Relating core stability to on court movements that coaching staff work on are the first three steps of acceleration. Quickness of initiation of the first three steps is a critical element in basketball for offence and defence. Stepping either fast or slow requires elevation of the pelvis for leg swing and hip flexion, most often from a hip flexed position with the player in a low stance. Considering the complex nature and role of the core musculature testing should include strength, endurance and how the core interacts with the periphery.

The first three steps of acceleration mentioned in the previous paragraph have a direct correlation to speed. Haryono et al., (2020) had 55 basketball players (35 male 20 females aged 17-22yrs) and found correlation between the Core Muscle Strength and Stability Test (CMSST) and 30m Acceleration Test (30 m-AT) showing the connection between speed and core activation. Further to this, studies have shown that speed itself is linked to performance, as elite players are quicker than non-elite players (Delextrat & Cohen., 2009, Sato and Mokha., 2009). Understanding the link to performance in basketball and core. Muscle activation and strength has been shown by Sharrock et al. (2011) when they conducted a series of 5 tests including double leg lowering as the core test and forty-yard dash, T-test medicine ball throw and vertical jump as performance tests. The study showed a correlation between the physical performance tests and core stability, in particular the medicine ball throw. To move this conclusion closer to basketball specific athletes, Arora et al. (2021) recent study found and increase in core activation and one arm hop test and modified upper quarter Y balance test in 36 male basketball players. This study suggests the concentric and eccentric actions alongside the proprioceptive and balance, strength and range of motion required during the technical shooting of a basketball are in part mimicked during the two tests. The evidence from this and other studies considering lower limb performance and core activation and strength show that the core is an important factor in sport performance.

One sport specific core muscle strength endurance test, commonly known as prone bridge plank, was used combined with upper and lower extremity movement prior to validation (Mackenzie, 2005). The prone bridge plank test has been described, as the sport specific plank test and is valid and reliable even though a sample size of 28 is small [ICC 0.99] (Tong et al., 2014). Electromyograhic data from this study tells me rectus abdominus and external obliques are most utilised during the test that works through 8 stages and is then repeated until failure (Tong et al., 2014) . This is a departure from Mackenzie's (2005) original format due to beliefs that core muscular endurance is essential for stability, as oppose to pure strength (Hibbs et al., 2008). Martuscello et al., (2013) considered muscle activation for multifidus and transversus abdominis during swiss ball, core stability and free weights. The study found that transversus abdominis had greater muscle activation during free weight exercises. In addition to the Martuscello study another paper considers both lower and upper rectus abdominis and external and internal obliques during swiss ball and traditional core stability exercises. The findings showed specific exercises have varying effects on muscle activation. Rectus abdominis had a greater level of MVIC for the roll out exercise, whereas internal and external obliques was greater MVIC for pike exercise (Escamilla et al., (2010). The need for athletes to produce complex multi-joint movements at varying speeds differs significantly from the isometric activity for rehabilitation that relies heavily on the torque of specific joints in specific positions (McGill, 2007; McGill et al., 2010) although, as already acknowledged, from experience it does have a place in injury prevention and rehabilitation.

The sport specific plank test works through eight stages[16] and repeats until failure. One familiarisation trial will be permitted as this is found to enhance reliability [ICC 0.97] (Tong et al., 2014) . Side plank left and right can identify asymmetries between sides as this test provides increased activation to quadratus lumborum thought to be fundamental in back stability and is a reliable test[17] [ICC 0.99] (Juker et al., 1998; McGill et al., 1996; McGill et al., 1999a; McGill et al., 2003) .

Hamstring Strength Endurance

Epidemiology in basketball is clear that ankle injuries are most prevalent in the sport (Starkey, 2000a; McKay et al., 2001b; McKay et al., 2001a; Dick et al., 2007) but risk of hamstring injury is also present with one 10 year study in National Basketball Association (NBA) showing a 2.5% rate of hamstring injury

[16] Sport specific endurance plank test: Stages – 1: Hold basic plank position for 60 s (Chinese press up position); Stage 2: Lift the right arm off the ground and hold for 15 s; Stage 3: Return the right arm to the ground and lift the left arm for 15 s; Stage 4: Return the left arm to the ground and lift the right leg for 15 s; Stage 5: Return the right leg to the ground and lift the left leg for 15 s; Stage 6: Lift both the left leg and right arm from the ground and hold for 15 s; Stage 7: Return the left leg and right arm to the ground, and lift both right leg and left arm off the ground for 15 s; Stage 8: Return to the basic plank position for 30 s; Repeat stages 1-8 until positions can no longer be maintained (Tong, Wu & Nie 2014) .

[17] Side plank test involves participants lying on their side on a mat with their feet and elbow of the lower arm supporting their weight. The foot of the upper leg is to be placed in front of the other leg. Participants are instructed to lift their hips from the floor and maintain the body in a straight-line position with the upper non-involved arm held across the body and placed on the opposing shoulder. The test is halted when the position can no longer be maintained allowing the hips to drop to the floor (Juker et al. 1998, McGill, Juker & Kropf 1996, McGill, Childs & Liebenson 1999b) .

across the study period that translates to 249 of the 9904 injuries recorded compared to 942 for ankle injuries (Starkey, 2000). A weakness in the injury data from Starkey (2000) is that all injuries are recorded using Athlete Exposure (AE) method instead of the widely recognised per 1000 hours method. AE does not fully and accurately compose the exact number of minutes during game play so does not discriminate between an athlete who played 1 minute against someone who played 40 minutes.

Freckleton & Pizzari's (2013) systematic review and meta-analysis of hamstring muscle injuries in sport revealed that quadriceps peak torque; previous hamstring injury and older ages are predictors of injury[18]. Common sport related movements of acceleration, deceleration, jumping and change of direction required in basketball provide a direct hamstring injury risk in sport (Devlin, 2000; Drezner, 2003). These movements demand muscle contraction in either concentric or eccentric at both high volumes repetitively and at high speed and as previously stated cannot be separated from trunk muscle activation.

Hamstrings are a key part in protection of the internal knee structure, notably the ACL and have been found to be associated with increased ACL injury risk if strength deficits and quadriceps dominance is present (Hewett et al. 2016, Myer et al. 2009, Myer, Ford and Hewitt, 2011). However, consideration to injury prevention for the knee and ACL injuries goes much wider than hamstring strength and endurance and is thought to require a comprehensive

[18] Four studies included in the meta-analysis with 195 participants for quadriceps peak torque. Seven studies with 3199 participants were included in the meta-analysis for age related injuries. Thirteen studies with 2952 participants were included in the previous hamstring injury meta-analysis.

neuromuscular injury prevention programme like the FIFA 11+ (Longo et al., 2012). This is not as clear cut as one would anticipate as the neuromuscular programmes are debated with systematic reviews with meta-analysis as inconclusive as to their effectiveness for ACL injury prevention in basketball (Taylor et al. 2015, Prodromos et al. 2007). Even though the neuromuscular injury prevention programmes are debated, they are effective in our academy setting where ACL injuries are rare. We also must focus on this PD and the setting and athletes I work with in basketball are all male, meaning, there is a gender difference in injury rates in the literature that is not applicable to the PD in an applied manner.

Opar et al. (2012) has highlighted but not conclusively confirmed that strength and endurance may be implicated in contributing to hamstring muscle injury risk. This has traditionally been difficult to test given the lack of reliable and validated tests for hamstring strength endurance. The Single Leg Hamstring Bridge Test (SLHB) has been used in athlete screening protocols in elite sport and is a reliable test both intra-tester and inter-tester ICC 0.77-0.88 and 0.89-0.91 respectively (Hallet, 2010). Freckleton, Cook & Pizzari (2014) have shown the Single Leg Hamstring Bridge to be associated with a risk factor of reduced hamstring muscle strength for hamstring muscle strain when used as a strength endurance test to failure. The SLHB makes the athlete raise one foot onto a 40 cm box and repeatedly drop and raise the pelvis from floor to bridge position to failure. This test puts the hamstring through a range of movement and contraction in a more functional position with both hip and knee flexed. Academy based testing has used this test for some years and I have also used it for elite youth athletics athletes. Athletes find this demanding even after a small number of repetitions with some cramping indicating poor hamstring strength endurance. As the SLHB is single leg test it shows asymmetries an athlete may have and is a test and tool that helps to shape training and rehabilitation protocols.

Upper Limb Strength Endurance and Power Tests.

Upper limb injuries are prevalent across many sports including basketball. Shoulder injuries in particular result in time loss from practice and competition, with over 40% of all athletes injured taking up to 1 week away from competition and training and 8% of all athletes injured being forced out for the remaining season (Robinson et al., 2014). Previously acknowledged epidemiology research in basketball has highlighted the prevalence of lower limb injuries in the sport, but those same studies do reveal significant upper limb injuries between 12.1%-23.2% of all basketball injuries across a season in both games and training (McKay et al., 2001b; Starkey, 2000b; Zuckerman et al., 2016).

The focus and prevalence put on lower limb injuries in basketball means there is a lack of physical performance screening tests for the upper limbs that are reliable and valid (Tarara et al., 2016). Many tests for the upper limb have been developed but are designed either for individual muscles or for different pathologies. However, these tests are not dynamic and therefore fail to address the functionality of performance (Kibler & Sciascia, 2008). Two tests have been identified as being reliable and can be related to function, albeit with limitations. These are the Closed Kinetic Chain Upper Extremity Stability Test and Unilateral Seated Shot Putt (Tarara et al., 2016; Goldbeck & Davies, 2000a; Ellenbecker et al., 2000; Taylor et al., 2016: Negrete et al., 2010: Gorman et al., 2012: Westrick et al., 2012) . The unilateral and asymmetrical movement required for Closed Kinetic Chain Upper Extremity Stability Test and Unilateral Seated Shot pertain to function by way of introducing more uncontrolled movement in a repeated and predictable form using one limb at a time that is more akin to sport related activity.

Closed Kinetic Chain Upper Extremity Stability Test

One recent systematic review showed moderate evidence for reliability and construct validity for Closed Kinetic Chain Upper Extremity Stability Test with consistent methods applied across the studies reviewed (Tarara et al., 2016). The number of touches achieved for active males during the Closed Kinetic Chain Upper Extremity Stability Test were 24.5 (Tucci et al., 2014). Closed Kinetic Chain Upper Extremity Stability Test is a simple but effective clinical and field based evaluation tool easily applied and has good test re-test reliability, [ICC 0.75] (Tucci et al., 2014). but is considered less applicable to populations other than athletes because of limitations in wrist, elbow, shoulder or torso strength when considering the position required to conduct the test (Goldbeck & Davies, 2000b). A limitation recognised by a review paper highlights the Closed Kinetic Chain Upper Extremity Stability Test cannot be used for injured athletes, as participants were not included who were young, athletic and injured (Tarara et al., 2016). If I consider a similar body position for the start of the Closed Kinetic Chain Upper Extremity Stability Test, it would be the press up position. To hold this position, you would need a reasonable degree of strength and would not be able to attain and hold the position with injuries to the upper limb. This is also a position hard to hold with poor strength, something I have experienced in the younger U14 age group at the basketball club that I work with, so my experience would concur with Tarara et al. (2016).

Closed Kinetic Chain Upper Extremity Stability Test is applied by assuming a press up position with hands 36” apart and touching a tape placed directly under each hand with the opposite hand. The athlete makes as many touches in 15 seconds as possible, with 45 seconds rest in-between whilst controlling pelvic movement and rotation (Goldbeck & Davies, 2000b). The test is repeated three times. Normalisation of data is not applied due to the complex neuromuscular movement involved in sport means many confounding factors could influence performance and can be complex to apply in the field (Vanderburgh, 1998, Vanderburgh & Laubach, 2008). However, one recent study has used a calculation to level the playing field in terms of scores by counting the number of touches and dividing this by participant height (Tucci et al., 2014). This correction is not deemed relevant for studies that aim to examine correlation with game performance outcomes or make physical comparisons between athletes as I do in this project.

Unilateral Seated Shot Putt

Unilateral Seated Shot Putt has also been regarded as reliable [ICC 0.98 dominant and 0.97 non-dominant] (Negrete et al., 2010). Unilateral Seated Shot Putt can be used to evaluate dominant versus non-dominant upper limbs power asymmetries and has been suggested to be the most appropriate test for evaluating performance in overhead athletes (Chmielewski et al., 2014; Tarara et al., 2016; Negrete et al., 2010). Unilateral Seated Shot Putt test allows for an evaluation of contralateral sides, but it should be noted that a significant proportion of throwing or passing in basketball is done with two hands akin to a chest pass. With a shot-putting action the arm utilizes an extension pattern of movement that differs from the torso rotation that athletes use when throwing. In recognition of some the limitations within the literature an alternative may be the Unilateral Seated Shot Putt and Seated Shot Putt double arm (commonly referred to as the chest push/pass). The Seated Shot Putt double arm has relevance to basketball specific movements but also allows us to compare unilateral and bilateral in performance outcomes thereby possibly guiding training and skill development. The strengths and weaknesses of athletes within academy age range display when passing is clearly observable. Some are able to pass single arm with accuracy and adequate power, others are only able to achieve this using the traditional chest push method. These tests potentially help me and coaching staff link what we see on court to what we measure during testing.

There is an inconsistency in the literature as to how the Unilateral Seated Shot Putt test has been applied and what weight has been used (Negrete et al., 2011; Negrete et al., 2010; Chmielewski et al., 2014) . The floor seated position used by Chmielewski et al. (2014) demands more technical ability from the participant to optimise trajectory. This is in stark contrast to being seated at 45° that by the nature of the seating angle removes the need to position the arm to an optimum trajectory angle (Negrete et al., 2011). For unilateral arm throw a weight of 2.75kg (nearest equivalent to 6lb) (Chmielewski et al., 2014; Negrete et al., 2010; Negrete et al., 2011) will be used and for bilateral putt 9kg will be used [ICC 0.92 males] (Clemons et al., 2010) . One notable point from a recent paper is that comparisons of bilateral upper limbs during unilateral seated shot throw showed no difference between dominant and non-dominant for both angles and heights of ball release (Riemann et al., 2018).

Normalisation need not be applied to these tests as in a clinical setting, it is usually achieved on a percentage basis comparing the uninjured side with injured as percentage deficit of the 100% 'normal' uninjured side. However, where no injury exists as in a pre-screening test, and the effect of dominance versus non-dominance, the efficacy of normalisation for this group is negated (Chmielewski et al., 2014).

Aerobic.

YoYo Intermittent Level 1.

The nature of basketball being high intensity exercise that is repeated in nature requires an athlete to train to maximise their anaerobic and aerobic system. The higher level an athlete is the better they perform on the YoYo Intermittent Recovery Test L1 (Yo-Yo IR1) (Bangsbo et al., 2008). There is some caution to be taken with Bangsbo et al. (2008) as many of the studies here are from unpublished data or personal communication. Having made this point those who perform well at the Yo-Yo IR1 test do tend to be in better physical shape in my academy and likely to get more game minutes. However, this is not always the case in national teams. Some athletes, particularly in U16 age group, rely on their natural physical development or skill to dominate and work less on their conditioning. This shows during testing at camp and during European Championships.

The Yo-Yo IR1 is a well-used and rehearsed test that allows coaches and support staff to evaluate an athlete's ability to sustain repeated bouts of intense exercise. Yo-Yo IR1 consists of 2 x 20m shuttle runs timed to an audio bleep with 10 seconds of rest interspersed between sets. Testing in 22 male basketball players aged 16.8 +/- 2 years has been found to significantly correlate with VO_{2max} (r=0.77, p=0.0001) and speed at VO_{2max} (r=0.71, p=0.0001, Castagna et al., 2008). Good Test-Retest Reliability for the Yo-YoIRL1 is evidenced by a test-retest ICC 0.95 (Thomas et al., 2006).

Consideration has been given to other tests and how they compare to use of the Yo-Yo IRL1. Bucheit and Rabbani (2012) considered the relationship between the Yo-Yo IRL 1 and the 30-15 Intermittent Fitness Test (30-15IFT). Findings from this study of 14 football players found a higher sensitivity to training for the Yo-Yo IRL 1 compared to the 30-15IFT although, the differences were minimal. High intensity intermittent exercise in the form of a 15/15 test to exhaustion was found to be similar in performance to both the Yo-Yo IRL 1 and Université de Montréal Track Test (UMTT) maximal aerobic velocity (MAV) (Dupont et al., (2008). The familiarity of the Yo-Yo IRL 1 coupled with the correlation to less well used tests generally but more specifically in basketball reinforces our current use of this test within the academy setting.

Further research has considered the often-used Single Line Drill Test (SLDT) otherwise known as the suicide run. Delextrat and Cohen, (2008) compared this with 16 basketball players of different levels, 8 elite and 8 non-elite. Findings from the study showed only a 0.06 secs difference between elite and non-elite players suggesting the SLDT is not able to discriminate between players of different levels and that the test does not replicate the anaerobic power measures that reflect modern basketball. However, Fatouros et al., (2011) studied the SDLT in 24 players, 12 in each the experimental and control groups. The study found that it was a valid, reliable, and sensitive tool of anaerobic capacity for basketball players. The difference between anaerobic power and capacity is one is maximal output for 5 secs and average over 30 seconds respectively. A further notable difference these two studies is Delextrat and Cohen (2008) was with ball in hand dribbling and Fatouros et al., (2011). This indicates and reinforces the need to move toward more sport specificity in testing.

The Yo-YoIRL1 is not dissimilar to the basketball specific line drill that uses a shuttle run employing court lines in a repeated and recovery method. The line drill test originally developed by Semenick (1990) was not deemed to be robust enough for this study as comparisons have been made to tests that are not aerobic (Hoffman et al., 2000). Carvalho et al. (2011) did find the line drill test able to discriminate between players at different levels. All of my academy players are classified as elite and the testing is not being used to classify players as part of talent identification. Yo-YoIRL1 is already used within the wider academy testing I conduct and is familiar to both coaches and athletes. Both the reliability of Yo-Yo IRL1 Test and functional relevance of use to basketball, coupled with the ease of application, means its use as a screening test as a measure of aerobic fitness will continue to be my method of choice.

The literature reviewed in this section highlights the wide array of tests sport performance professionals can choose. When I consider what test to use, I must provide thought to the sport involved and how close do I want a test to mimic sporting actions. This is important as I can try to relate tests to functional sport related movement either broken down into parts of movements or movements as a whole. I can never in team sports replicate the unpredictable nature of game play but may through testing be able to understand players strengths and weaknesses and how these impact performances.

A second and critically important element is to constantly evaluate where I am with testing and where I seek to develop my testing protocols. The academy tests each academic term (September, January and May). This has traditionally been focused on a form of the Yo-Yo test, vertical jump height, T-Test and core strength endurance tests like plank. Recent developments have moved to include some of the physical tests incorporated within this project but also the clinic-based testing. Testing will include some of the tests I use within my environment and some that I do not use to assess whether they relate to the competitive arena. The key point of correlating tests to game performance outcomes in one sport is essential in helping us to understand where athletes are in their development as basketball players. Furthermore, what is learnt from basketball testing may be cross-pollinated to other academy sports that are also tested generically.

Pulling together the sub-sections of the literature review from epidemiology, physiology, game statistics and understanding different testing types has provided a detailed all-encompassing view of what and how to apply testing in my environment. Linking the areas mentioned pushes me toward a more specific testing regimen that is tied to both performance and secondly injury risk factors.

The hypothesis is that some screening and physical test data will correlate with some selected game performance outcomes. It is expected that not all tests will show correlation, and this is part of the reason for testing that, in the future allows for refining of screening test for greater efficiency. To help add a clear pathway testing will be grouped into groups of similar characteristics that additionally aids in the management of data, given we are seeking a clear link form a test to each specific game performance outcome. This is explained in detail through the following methods section.

Chapter 3

Methods

Participants

19 Male athletes from an English elite basketball academy team were recruited and volunteered to participate. Age 17.2 ± 0.9 years, height 186.4 cm ± 11.1 cm using SECA 761 (SECA, Germany), weight 81.0 Kg ± 11.5 Kg using SECA 217 (SECA, Germany) was collected at the start of the academic year. Ethics approval was provided via University of Kent, Faculty of Sciences (see Appendix 1). Each participant gave informed consent form after reading the participant information sheet (see Appendices 2 & 3). Players completed three sessions of pre-season screening (September, second week) conducted in the afternoon as circadian research suggests peak power output is greater at this time (Teo et al., 2011) . Sessions were shaped to reduce the effects of one test on the superseding test which is why strength endurance tests were placed last as these are to exhaustion. Both the jump and speed tests are spread across two sessions two days apart to reduce fatigue and subsequent negative effects on performance. It must be recognised that during the test period my athletes were still involved in their normal training routine that is two hours of basketball per day with two strength and conditioning and individual basketball skill sessions per week lasting 1 to 1.5 hours per week. Sessions were completed every other day across one week that fits with academy testing timeframe. Rest between individual tests and repetitions are guided by each test protocol and the academy's natural flow of athletes moving through a circuit-based testing system. I have been conscious to replicate academy life in the norm and not to manipulate

an environment that is not what we do nor will be replicated in future testing. In essence it is applied as per the Professional Doctorate should be.

Reliability measures detailed throughout the previous tests specific literature review section are sufficiently reliable to detect changes over the course of the study. Each measure with mean and standard deviation (SD) are listed within descriptive statistics tables in the results section pages 115-120. Although we acknowledge testing is over a short period of time and no follow testing was completed, intra-individual variation can occur across time for game statistics that could influence inter-individual variation. These factors could include biological error and biological variation as well as researcher error. We are aware as an academy of day-to-day changes in players and the many stressors that may affect performance in testing and during training and games. Atkinson & Baterham (2015) suggest continuous scale measures have both a true value and additional error. To try to limit this repeated trials should be applied but, in my setting, and resources available, this is not possible to achieve, a point highlighted by Oliver et al., (2020). Our testing will consist of 3 sessions detailed in the following paragraphs.

Session 1: Baseline range of movement passive and active tests including: shoulder internal; external rotation; hip internal; external rotation; ankle plantar; dorsi-flexion and weight bearing lunge test conducted in a physiotherapy clinical setting.

Session 2: Conducted in a sports hall setting and will include: single leg squat; Y Balance test; Vertical jump protocols (excluding ground reaction time and reactive strength index); both 5m and 10m Speed tests for lower limb tests. Upper limb testing in session 2 includes: Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST); Unilateral Seated Shot Putt (USSP) and Bilateral Seated Throw.

Session 3: As is session two the sport hall will be the environment for sessions three. This will include: 4-jump protocol for ground reaction time and reactive strength index; 20m and 30m speed tests; reactive and non-reactive agility tests; torso strength endurance tests and hamstring strength endurance test.

Agility T-Test and Yo-Yo Intermittent test are done in a separate session as part of a standardised academy testing protocol for all sports.

Performance data utilising Elite Academy Basketball League (EABL) game statistics throughout the season were used to consider correlations with test outcomes as was all injury data across one complete season and academic year. Game statistic data will be detailed under the game statistics section toward the end of the chapter. A chartered physiotherapist (myself) who leads the academy medical department and records all injuries collated injury data. The physiotherapist determined whether a player is injured or not, if the injury is time loss or non-time loss and records the number of injuries. All injury information is recorded on the academy's secure medical records system CSMI Sportsware

Online (Massachusetts, USA) with the relevant injury statistics extracted for analysis and correlation.

Procedures

Range of Motion Baseline Testing.

Range of Motion was measured using two devices. Most tests utilised the Inclinometer - Baseline® Bubble Inclinometer (New York, USA) and/or the Goniometer - Baseline® Plastic Goniometer (New York, USA). Both measuring tools provide a measurement in degrees (°).

Shoulder Internal rotation active and passive.

Participants adopted a supine position on a physiotherapy plinth with shoulder at 90° abduction. An Inclinometer - Baseline® Bubble Inclinometer (New York, USA) was placed on dorsal aspect of distal forearm and elbow stabilized flexed to 90° to reduce unwanted movement. The arm was taken passively into internal rotation. A towel was placed under the participants upper arm parallel with the plinth to ensure the shoulder did not drop into extension. This procedure is repeated but the participant was asked to now complete the task actively (Cool et al. 2005) (see Appendix 5, illustration a).

Shoulder External rotation active and passive.

Participants adopted a supine position on a physiotherapy plinth with shoulder at 90° abduction. An Inclinometer - Baseline® Bubble Inclinometer (New York, USA) was placed on the palmar aspect of distal forearm and the elbow, flexed to 90° was stabilized to reduce unwanted movement. The arm was taken passively into external rotation. A towel was placed under the participants upper arm parallel with the plinth to ensure the shoulder did not drop into extension. This procedure is repeated with the participant asked to now complete the task actively. A measure was taken in degrees (°) with the Inclinometer - Baseline® Bubble Inclinometer (New York, USA) (Cool et al. 2005) (see Appendix 5, illustration b).

Hip Internal and External Rotation active and passive.

Participants adopted a prone position on a physiotherapy plinth and flexed one knee to a deep flexion position with the foot on the plinth and allowed the contralateral leg to hang off the end of the plinth at 90°. The physiotherapist placed the Inclinometer - Baseline® Bubble Inclinometer (New York, USA) over the natural curve of the medial malleoli. The leg was then rotated into medial rotation (outward movement) where a measure was taken and then into lateral rotation (inward movement) where a second measurement was taken. A pause to recalibrate and check the start position between internal and external rotation is required at the original start point. This procedure is repeated with the participant asked to now complete the task actively. Measures taken were in degrees (°) with the Inclinometer - Baseline® Bubble Inclinometer (New York, USA) (Charlton et al., 2015) (see Appendix 5, illustration c & d).

Straight Leg Raise.

Participants adopted a supine position on the physiotherapy plinth. The physiotherapist placed an Inclinometer - Baseline® Bubble Inclinometer (New York, USA) on the distal anterior thigh and placed one hand under the heel of the same leg. A strap applied downward pressure on the opposing, leg keeping it flat on the plinth. The physiotherapist passively raised the test leg by taking the hip into flexion to the point of resistance taking a measure from the inclinometer to objectively consider hamstring length. The physiotherapist also noted any neural symptoms (increased tension, pins and needles, numbness and pain along the pathway of sciatic nerve). This procedure was repeated for the opposite leg. Measures taken were in degrees (°) with the Inclinometer - Baseline® Bubble Inclinometer (New York, USA) (Boyd, 2012) (see Appendix 5, illustration e).

Hamstring 90/90 Test.

Participants adopted a supine position on the physiotherapy plinth and flexed the left hip and knee to 90°**.** The physiotherapist placed one hand over the heel of the flexed leg and placed the Inclinometer - Baseline® Bubble Inclinometer (New York, USA) over the tibial tuberosity with the other hand. The lower leg was then passively taken toward knee extension whilst maintaining the hip at 90° and a measurement from the inclinometer was taken at the end of ROM. This procedure is repeated for the opposite leg. Measures taken were in degrees (°) with the Inclinometer - Baseline® Bubble Inclinometer (New York, USA) (Hamid et al., 2013) (see Appendix 5, illustration f).

Ankle Dorsi and Plantar Flexion active and passive.

Participants were long sitting with both feet off the end of the physiotherapy plinth at approximately mid-calf position. A Goniometer - Baseline® Plastic Goniometer (New York, USA) was held in place with one arm aligned to the fibula from the lateral malleoli and the other along the lateral aspect of the foot. Start position is 90°. The physiotherapist placed one hand on the mid tibia to stabilize and fix one arm of the goniometer, and the other on the plantar aspect of the midfoot fixing the other goniometer arm. The physiotherapist moved the foot into full dorsi flexion to the end ROM where a measurement is recorded. The foot was then taken to the 90° start position and with the same handling the foot was then taken into plantar flexion to the end range where a measurement was recorded. The procedure is repeated with the participant now asked to do this actively. Measures taken were in degrees (°) with the Goniometer - Baseline® Bubble Inclinometer (New York, USA) (Ness et al., 2018, Russell et al., 2010, Krause et al., 2011) (see Appendix 5, illustration g & h).

Adductor Squeeze Test.

The participants adopted a supine position on the physiotherapy plinth with hips and knees at 45° and feet flat on the plinth. The biofeedback pressure gauge (IDASS, UK) was placed between the participant's knees ensuring the gauge and pressure is pre-set to 10mmHg. Participants were asked to squeeze their knees together without bracing through the back and neck and to do so progressively with sight of the gauge to aid in motivation. Three attempts were made with the highest recorded and any pain noted. Measures taken were in millimetres of mercury (mmHg) with a biofeedback pressure gauge (IDASS, UK) (Delahunt et al., 2011) (see Appendix 5, illustration i).

Dynamic Functional Testing.

Weight Bearing Lunge Test.

A straight line was placed on the floor with a tape measure and up the wall just beyond the height of the knee. The participant placed the right foot over the centre of the line on the floor and dorsi-flexed the ankle and flexed knee until the knee touched the wall. This process was repeated whilst moving the foot away from the wall until the lunge movement does not allow the knee to touch the wall without the heel lifting from the floor. Once the maximal ankle dorsiflexion was found a measure was taken from the great toe to the wall in centimetres and with the Inclinometer - Baseline® Bubble Inclinometer (New York, USA) that was placed along the tibia below the tibial tuberosity. Measures taken were in degrees (°) with the Goniometer - Baseline® Bubble Inclinometer (New York, USA) (Hoch et al., 2011) (see Appendix 5, illustration x).

Y Balance Test

Participants were allowed six trials to negate learning effect on the Y balance test before three test trials. The great toe was placed at the centre point and the participant transferred weight to a single leg stance position and reached in the anterior, posteromedial and then posterolateral direction with the non-stance leg. The maximal point of reach was measured with a standard cloth tape measure. All three trials for each limb and direction were recorded. Trials were deemed failed if the participant failed to maintain unilateral stance, lifted or moved the stance foot from the initial start position, touches down with the rear foot or failed to return to the start position. The starting stance leg will be the non-dominant leg. Distance reached was taken in centimetres (cm) (Plisky et al. 2006) (see Appendix 5, illustration j).

Leg length may influence results, but this has been normalized for both the SEBT and Y test by converting the result to a percentage (*stance leg length ÷ reach distance* X 100). Composite values are also calculated by the sum of three reach directions divided by the sum of three times leg length multiplied by 100 (Gribble et al., 2012; Plisky et al., 2006; Shaffer et al., 2013).

Qualitative Assessment Single Leg Squat (QASLS)

Participants were instructed to conduct five single leg squats (QASLS) on each leg to a comfortable depth between 45° - 60° with arms remaining relaxed at the side of the trunk. Participants were asked to keep their knee aligned with the second toe and maintain trunk alignment and knee control. This test was completed barefoot to fully assess foot motion and was video recorded from a 3m distance (Sony Alpha A65 SLT Digital Camera (Tokyo, Japan), Hama® Star 62 Tripod (Monheim, Germany). QASLS evaluated arm strategy, trunk alignment, pelvic plane, thigh motion, knee position, and steady stance, and is scored out of 10 with 0 being the optimum (see Appendix 4 for full QASLS criteria) Herrington & Munro, 2014) (see Appendix 5, illustration k).

Double Leg Vertical Jump

Participants performed three maximal double leg countermovement jumps using arms in a normal jump swinging motion. There was a 30 second rest period between each repetition. Jump height was measured using the Just Jump System (Probiotics, Huntsville, AL). Instructions were to partially squat to a countermovement position and explode up jumping as high as you can and ensure you land back on the mat. The Just Jump System (Probiotics, Huntsville, AL) provided a measurement in centimetres (cm) for this test (Slinde et al., 2008) (see Appendix 5, illustration l).

Single Leg Vertical Jump

Participants performed three maximal single leg countermovement jumps on each leg using arms in a normal jump swinging motion. There was a 10 second rest period between each repetition as each side was tested alternating so minimal rest was required. Jump height was measured using the Just Jump System (Probiotics, Huntsville, AL). Instructions were to partially single leg squat to a countermovement position and explode up jumping as high as you can and ensure you land back on the mat. The Just Jump System (Probiotics, Huntsville, AL) provided a measurement in centimetres (cm) for this test (Slinde et al., 2008) (see Appendix 5, illustration m).

Double Leg Vertical Jump To Basketball Backboard

Participants performed three maximal double leg countermovement jumps using arms in a normal jump swinging motion in front of an on-court basketball backboard. There was a 30 second rest period between each repetition. Jump height was measured using the Just Jump System (Probiotics, Huntsville, AL). Instructions were to partially squat to a countermovement position and explode up jumping as high as you can, touch the backboard at the highest point you can reach and ensure you land back on the mat. Backboard touch can be with one hand. The Just Jump System (Probiotics, Huntsville, AL) provided a measurement in centimetres (cm) for this test (Slinde et al., 2008) (see Appendix 5, illustration n).

Single Leg Vertical Jump To Basketball Backboard

Participants performed three maximal single leg countermovement jumps on each leg using arms in a normal jump swinging motion in front of an on-court basketball backboard. There was a 10 second rest period between each repetition as each side was tested alternating so minimal rest was required. Jump height was measured using the Just Jump System (Probiotics, Huntsville, AL). Instructions were to partially single leg squat to a countermovement position and explode up jumping as high as you can touching the backboard at your highest point and ensure you land back on the mat. Backboard touch can be with one hand. The Just Jump System (Probiotics, Huntsville, AL) provided a measurement in centimetres (cm) for this test (Slinde et al., 2008) (see Appendix 5, illustration o).

Double Leg Vertical Jump To Target Basketball

Participants performed three maximal double leg countermovement jumps using arms in a normal jump swinging motion whilst simultaneously reaching as high as they can to catch and hold a basketball thrown in the air. There was a 30 second rest period between each repetition. Jump height was measured using the Just Jump System (Probiotics, Huntsville, AL). Instructions were to partially squat to a countermovement position and explode up jumping as high as you can, catch the basketball at the highest point you can reach and ensure you land back on the mat. Basketball can be caught with one hand on initial contact. The Just Jump System (Probiotics, Huntsville, AL) provided a measurement in centimetres (cm) for this test (Slinde et al., 2008) (see Appendix 5, illustration n).

Single Leg Vertical Jump To Target Basketball

Participants performed three maximal single leg countermovement jumps on each leg using arms in a normal jump swinging motion whilst simultaneously reaching as high as they can to catch and hold a basketball thrown in the air. There was a 10 second rest period between each repetition as each leg will be tested alternating so minimal rest is required. Jump height was measured using the Just Jump System (Probiotics, Huntsville, AL). Instructions were to partially single leg squat to a countermovement position and explode up jumping as high as you can, catch the basketball at the highest point you can reach and ensure you land back on the mat. Basketball can be caught with one hand on initial contact. The Just Jump System (Probiotics, Huntsville, AL) provided a measurement in centimetres (cm) for this test (Slinde et al., 2008) (see Appendix 5, illustration o).

Ground Contact Time

Participants performed four consecutive maximal countermovement jumps on both double and single legs with normal arm swinging motion using the 4 Jump Protocol on the Just Jump System (Probiotics, Huntsville, AL). Data from the system will provide both average height in centimetres (cm) and ground contact time in seconds (secs) across the four jumps. This four-jump protocol was tested once for double and left and right single leg. Instructions were to partially squat / single leg squat to a countermovement position and explode up jumping as high as you can, repeatedly for four jumps. Try to minimise the amount of time your feet are in contact with the mat, ensuring you land on the jump mat after each jump (McMahon et al., 2016).

Reactive Strength Index (RSI)

RSI was measured during the Ground Contact Time four jump test by using the existing data the test produces. Reactive Strength Index used the average jump height (cm) divided by the ground contact time (secs) to provide Reactive Strength Index on both single and double leg vertical jumps on Just Jump System (Suchomel et al., 2015) (Probiotics, Huntsville, AL).

Linear Speed Tests- 5m; 10m; 20m.

Participants completed three sprint tests over each distance of 5m, 10m and 20m. These were all maximal tests and data was collected for all three tests and a mean used for comparisons. Timing gates (Smart Speed, Fusion Sport, Brisbane, Australia) were set at the exact distance apart relevant to the distance to be tested (5m, 10m, 20m) and participants started 0.3m behind the timing gate line. Participants were given the command go for each repetition. Work rest ratio will be determined by how many athletes are in each group. Data was gathered through Smart Speed software (Smart Speed, Fusion Sport, Brisbane, Australia) and is in seconds (secs) (Sayers, 2015) (see Appendix 5, illustration p).

Reactive and Non-Reactive Agility Test.

Participants positioned themselves in the centre of an 8m square that has four gates (Smart Speed, Fusion Sport, Brisbane, Australia) set at each corner. Participants sprinted through each gate 4 times meaning a total of 16 gates. This was either in a pre-planned route for non-reactive, or random sequence for reactive. The random sequence was be triggered by light stimulus. Each participant completed three trials of each reactive and non-reactive protocol. Additionally, there was one familiarisation trial. The mean of all trials was calculated for both reactive and non-reactive agility test. The layout of the agility tests can be seen in Figure 3.1, also displaying the route of the non-reactive test. Data was gathered through Smart Speed software (Smart Speed, Fusion Sport, Brisbane, Australia) and is in seconds (secs) (Oliver & Meyers, 2009) (see Appendix 5, illustration q). Furthermore, the Agility T-Test will be used as a standard non-reactive agility test based on Semenick's protocol (Semenick, 1990).

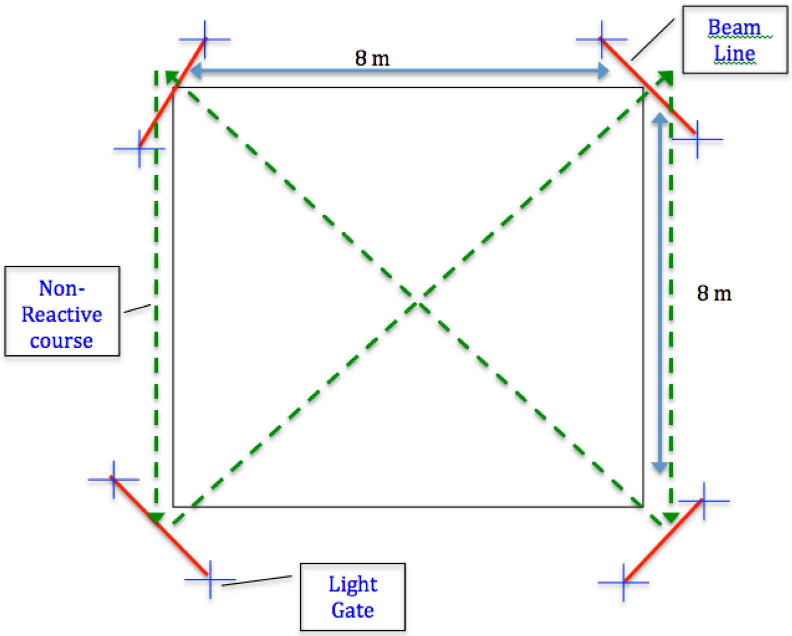


Figure 3.1 Reactive and non-reactive tests

Reactive test is for participants to pass through each gate randomly. Gates are represented by the blue cross with the timing beam the red line connecting them. Non-reactive the participants follow a set route indicated by the broken green line again passing through each gate four times.

Torso Strength Endurance Tests.

Sport specific endurance plank test:

Participants positioned themselves in a prone plank position otherwise known as a Chinese Press Up position with contact on toes and forearms on the floor at a set distance of hip and shoulder width apart respectively measured between 1st metatarsals of the foot and medial epicondyles of the elbow. Head is in neutral and body is aligned so the hip is placed in the middle of two 80cm strings 10 cm apart for guidance as to hip position from a side view. Any deviation from this position and one warning was given and then test then stopped. Hands were flat on the floor palms down.

Stages – 1: Hold basic plank position for 60s; Stage 2: Lift the right arm off the ground and hold for 15s; Stage 3: Return the right arm to the ground and lift the left arm for 15s; Stage 4: Return the left arm to the ground and lift the right leg for 15s; Stage 5: Return the right leg to the ground and lift the left leg for 15s; Stage 6: Lift both the left leg and right arm from the ground and hold for 15s; Stage 7: Return the left leg and right arm to the ground, and lift both right leg and left arm off the ground for 15s; Stage 8: Return to the basic plank position for 30s; Repeat stages 1-8 until positions can no longer be maintained (Tong et al., 2014) . Time is measured and recorded in seconds (see Appendix 5, illustration r).

Side Plank Endurance Test.

Participants adopted position on their side on a mat with their feet and elbow of the lower arm supporting their weight. The foot of the upper leg was placed in front of the other leg. Participants were instructed to lift their hips from the floor and maintain the body in a straight-line position with the upper non-involved arm held across the body and placed on the opposing shoulder. The test was halted when the position can no longer be maintained, allowing the hips to drop to the floor (Juker et al., 1998; McGill et al., 1996; McGill et al., 1999b) .

Time is measured and recorded in seconds (see Appendix 5, illustration s).

Single Leg Hamstring Bridge (SLHB) Test.

Participants lay supine on a gym mat and place one foot / heel on a 60cm box and position the body, so the knee of the raised leg is at approximately 20° of knee flexion. Arms are crossed and place on the chest. Participants were instructed to push down through the heel and raise the pelvis from the floor until the hip reaches a neutral position of 0°. The pelvis was lowered to the floor as in the start position without resting down and the process is then repeated to failure. Participants were given one warning if the pelvis failed to reach the correct position with recurrence resulting in a stopped test. The non-working leg was held in a static vertical position to avoid assistance of momentum by additional swing movement. This protocol was repeated for each leg and only one trial is used due to the fatigue element (Freckleton et al., 2014) . The number of repetitions are recorded (see Appendix 5, illustration t).

Closed Kinetic Chain Upper Extremity Test (CKCUEST).

Two pieces of white zinc oxide tape were placed parallel to one another each 6"in length and 36" apart. Participants assumed the push up position placing each hand on the tape with the middle finger central to the tape. On instruction participants lifted one arm and touched it on the tape just under/in front of the contralateral arm then returned it to the start point. This was then repeated for the opposite arm. The process of alternate hand touching was repeated as fast as possible for 15 seconds with participants allowed 3 trials and one familiarisation submaximal trial. Rest between each trial was 45 seconds. Each touch was counted, and a mean taken from the three trials. Participants must control pelvic rotation and maintain the push up position. Work-rest ratio for this test is 1:3 (Goldbeck & Davies, 2000a) (see Appendix 5, illustration u).

Unilateral Seated Shot Putt (USSP).

Participants assumed a seated position on a 45° incline bench that was positioned against a wall for stability. Feet were placed flat on the floor. The participant took the 2.75kg-weighted medicine ball with one arm and moved it toward the unilateral shoulder. The non-involved arm was placed on the opposite shoulder. The medicine ball was pushed forward in a putting action using upper extremity strength and power only and no involvement of back, neck or arm countermovement. Participants should project the medicine ball at 45° for optimal angle trajectory as far as they can. Three attempts were given with a mean taken. Two-familiarisation trials were allowed. Measurement was taken by a standard tape measure that was placed level with the most forward position of the ball while the arm is in the cocked position (nearest to the shoulder) and stretched out to the end of the tape. The point of contact with the ball on the floor is the distance recorded in meters. This procedure was repeated with the contralateral arm. Guidance for the participant is to keep the ball in a straight line as possible and as near to 45° as possible (Clemons et al., 2010; Negrete et al., 2011) (see Appendix 5, illustration v).

Bilateral Seated Chest Push.

Participants adopted a seated position on a 45° incline bench that was positioned against a wall for stability. Feet were placed flat on the floor. The participant took the 9kg-weighted medicine ball with both arms and brought it toward their chest. The medicine ball was pushed forward in a chest pass action using upper extremity strength and power only and no involvement of back or neck. Participants should aim to project the medicine ball at 45° for optimal angle trajectory as far as they can. Three attempts are given with a mean taken. Two-familiarisation trials are allowed. Measurement was taken by a standard tape measure that is placed level with the most forward position of the ball, while the arm is in the cocked position (nearest to the chest) and stretched out to the end of the tape. The point of contact with the ball on the floor is the distance recorded in meters and marked with a piece of chalk. Guidance for the participant is to keep the ball in a straight line as possible and as near to 45° as possible (Clemons et al., 2010) (see Appendix 5, illustration w).

Yo-Yo Intermittent Recovery Level 1

Yo-Yo IR1 will consist of 2 x 20m shuttle runs timed to an audio bleep with 10 seconds of rest interspersed between sets (Bangsbo et al 2008; Thomas et al., 2006).

Game Statistics

Table 3.1 Game statistics and definition used for correlation with screening tests

Game statistic	Description
Number of Games Played Season	This is the number of games each player participates in through the season.
2pts Field goal % Season Average	The percentage of 2pt shots made across a full season. A 2pt field goal is a basket/score made from inside the 3-point line not including a free throw.
3pts Field Goal % Season Average	The percentage of 3pt shots made across a full season. A 3pt field goal is a successful basket taken from beyond the 3-point arc/line.
Free Throws made Season Average	The number of free throws made across the season. A free throw is a shot taken from behind the free throw line and is unchallenged as they are awarded because of a foul.
Free Throws % Season Average	The percentage of free throws made across the season. A free throw is a shot taken from behind the free throw line and is unchallenged as they are awarded because of a foul.
Offensive Rebounds Season Average	The number of offensive rebounds made across the season.
Defensive Rebounds Season Average	The number of defensive rebounds made across the season.
Assists Season Average	The number of assists made across the season.
Steals Season Average	The number of steals made across the season.
Blocked Shots Season Average	The number of blocked shots across the season.
Total Points Season Average	The total number of points across the season.

Statistical analysis.

To analyse the present data, several steps were undertaken. First, following recommendations (Hahs-Vaughn, 2017), the data were checked for normality via the Shapiro-Wilk Test. Secondly, to examine relationships between physical performance tests, game statistics, and injury data, Pearson's correlations were calculated. Values of *r* are based on Evans (1996) guide as follows: .00-.19 = very weak; .20-.39 = weak; .40-.59 = moderate; .60-.79 = strong; .80-1.0 very strong. Statistical significance was set at $p < .05$. All analyses were conducted using IBM SPSS Version 23 (NY, USA). We conducted a post-hoc (a posteriori) power analysis in G*Power 3.01 which indicated that with our sample size (N = 19) we had .78 power to detect an effect size of r = .50 at an alpha level of .05. This effect size was selected because it indicates that moderate or large effect size is more meaningful, and that this meets common criteria for sufficient power (Cohen, 2008; Lakens, 2021).

Further analysis was conducted using Multiple Linear Regression Analysis using IBM SPSS Version 23 (NY, USA). This focused on four models based on logical court activity (Active ROM) and significant correlation data. Model 1 considers Active ROM at upper and lower limb joints with 2pt Field Goal Percentage Season Total. Model 2 considers lower limb Passive ROM parameters and Free Throw Percentage Season Total. Model 3 considers lower limb ROM and agility and speed parameters with Assists Season Average. Model 4 considers lower limb ROM and agility and speed parameters with Steals Season Average.

Injury data has been categorised into four areas: 1. Did the athlete sustain injury; 2. Time loss injury; 3. Non time loss injury; 4. Total number of injuries. The first 3 of this lists is a yes/no converted to a numerical label, whereas 4. is a total number. The small sample size and low injury numbers provides the basis for this statistical approach that is using a point biserial correlation with games statistics as the continuous variable and injury data as the dichotomous variable.

To simplify the presentation of analyses, physical performance tests were grouped according to similarities and to allow adequate recovery (Burr et al., 2008; McGill et al., 2012). This resulted in 6 groups: (1) Baseline Clinical Tests; (2) Neuromuscular Tests; (3) Comparative Upper Limb and Physical Tests + CKCUEST; (4) Strength Endurance and Stability; (5) Agility and Speed; (6) Jump Tests and Reactive Strength Index. See Figures 3:2 to 3:7 for a more detailed overview of these groupings.

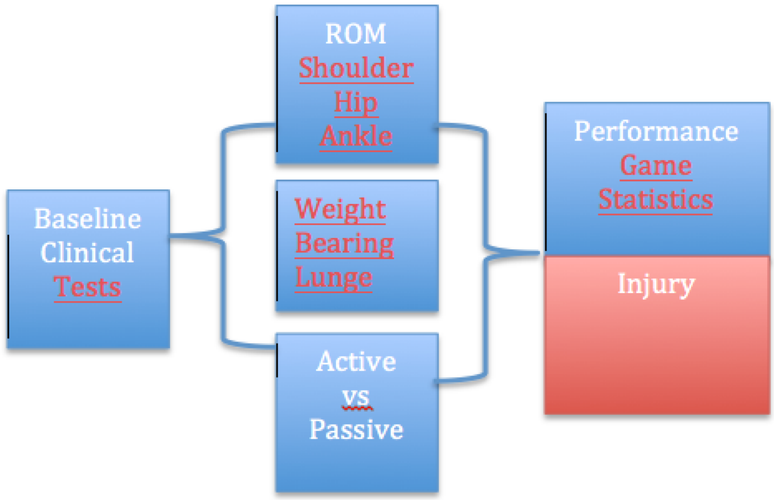


Figure 3.2 (1) Baseline Clinical tests

(1) Baseline Clinical Tests. Tests included in this group were all range of movement tests for both active and passive movements. The weight bearing lunge test was also included as it measures range of movement. All of these tests were correlated with injuries and performance.

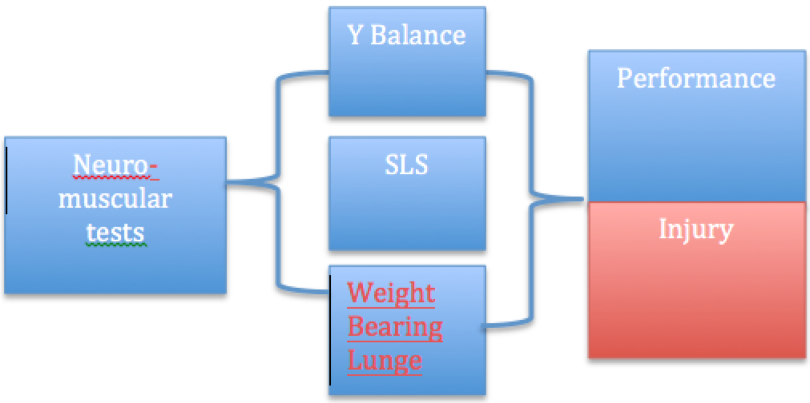


Figure 3.3 (2) Neuromuscular tests

(2) Neuromuscular tests. Tests in this group were neuromuscular tests including Y balance and Qualitative Assessment Single Leg Squat (SLS). All of these tests were analysed for correlation with injuries and performance.

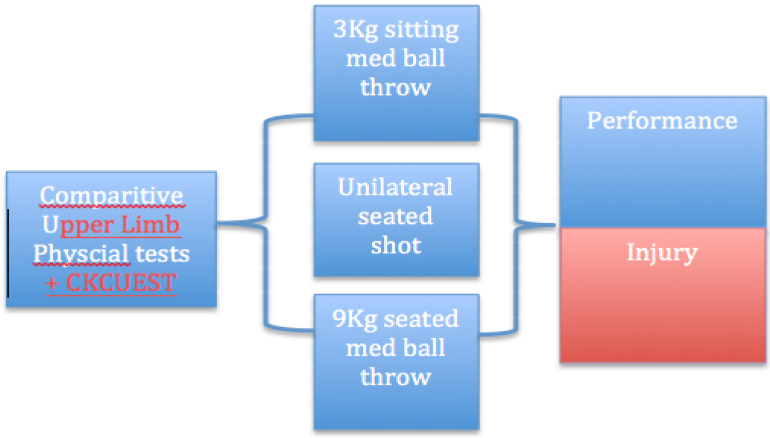


Figure 3.4 (3) Upper limb physical tests

(3) Upper limb physical tests. Tests in this group were based on upper limb testing. Tests included 3kg unilateral seated shot, 9Kg medicine ball seated chest push, and 3Kg seated medicine ball chest push. All of these tests were analysed for correlation with injuries and performance.

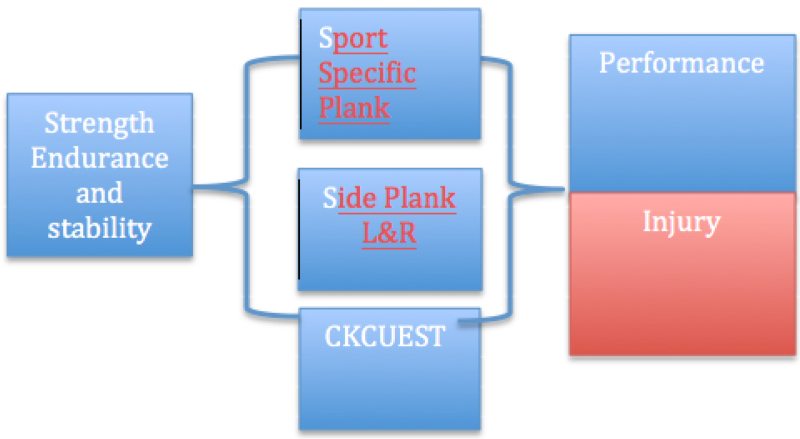


Figure 3.5 (4) Strength endurance tests and stability

(4) Strength endurance tests and stability. Tests in this group were focused on strength endurance of the core and elements of upper limb control alongside

core endurance. Tests included sport specific plank, side plank and CKCUEST. All of these tests were analysed for correlation with injuries and performance.

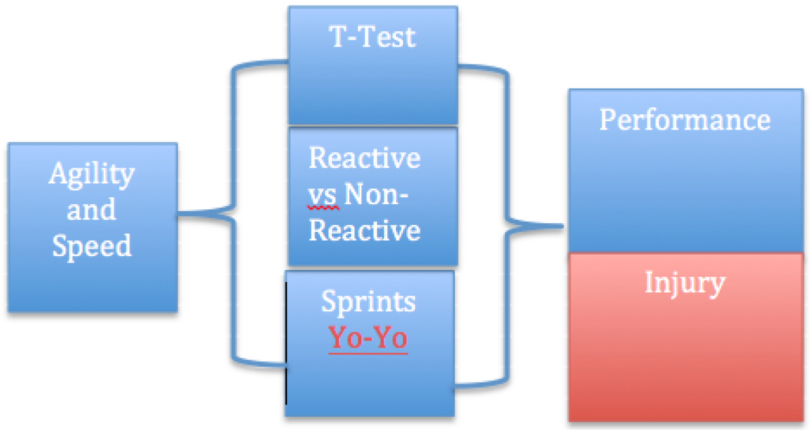


Figure 3.6 (5) Agility and speed tests

(5) Agility and speed tests. Tests in this group are focused on speed and agility tests. Tests included the agility T-test, both reactive and non-reactive agility tests, and the Yo-Yo test, and sprint tests at 3 distances. All of these tests were analysed for correlation with injuries and performance.

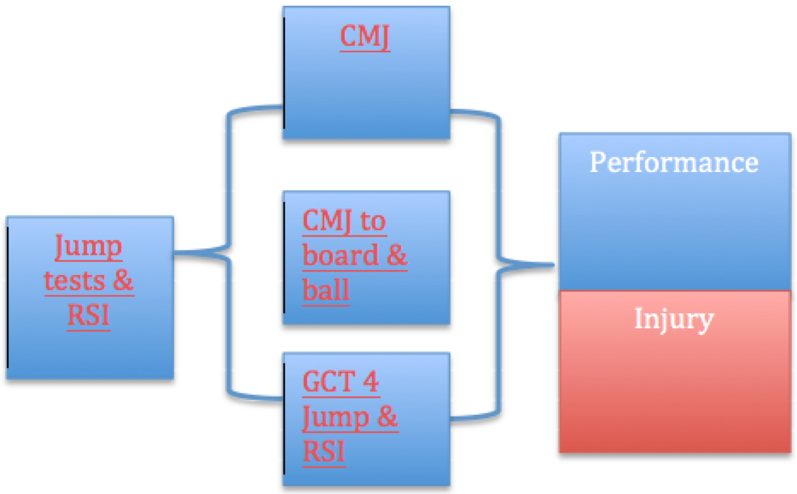


Figure 3.7 (6) Jump test protocols and reactive strength index (RSI)

(6) Jump test protocols and reactive strength index (RSI). Tests in this group focused on power-based activities around vertical jumping and associated calculations from the jump data like Reactive Strength Index (RSI). Tests included were counter movement jump (CMJ) of three variations (normal, backboard and ball target) both double and single leg. 4-jump protocol was also used to determine ground contact time for repeated jumping. All of these tests were analysed for correlation with injuries and performance.

Chapter 4

Results.

Complete data were obtained from 19 athletes all of whom were male. All descriptive statistics for screening variables and performance outcomes (*N*, Mean ± *SD*) are presented in Tables 4:1 to 4:6.

In the subsequent sections, the correlations between tests, performance tests, and injury data are presented. The order of these follows on from the models outlined on pages 109-112 above. Multiple Regression Analysis models follow at the end of the results section.

Table 4.1 Baseline and ROM upper limb and hip descriptive statistics (N=19)

	Mean	Std. Deviation
Age (y)	17	0.9
Height (cm)	186	11.2
Weight (Kg)	81.0	11.5
Left Shoulder Passive Int Rot (°)	73.0	12.4
Right Shoulder Passive Int Rot (°)	62.0	12.7
Left Shoulder Active Int Rot (°)	77.4	17.2
Right Shoulder Active Int Rot (°)	71.1	17.4
Left Shoulder Passive Ext Rot (°)	99.8	15.2
Right Shoulder Passive Ext Rot (°)	100.2	13.5
Left Shoulder Active Ext Rot (°)	101.6	12.4
Right Shoulder Active Ext Rot (°)	102.4	12.5
Left Hip Passive Int Rot (°)	43.3	13.0
Right Hip Passive Int Rot (°)	45.1	11.5
Left Hip Active Int Rot (°)	46.0	10.5
Right Hip Active Int Rot (°)	46.3	11.9
Left Hip Passive Ext Rot (°)	56.4	7.0
Right Hip Passive Ext Rot (°)	56.6	7.8
Left Hip Active Ext Rot (°)	57.8	6.4
Right Hip Active Ext Rot (°)	58.7	9.7

Table 4.2 Range of motion lower limb descriptive statistics (N=19)

	Mean	Std. Deviation
Left Plantar Flex Passive (°)	53.4	5.5
Right Plantar Flex Passive (°)	53.2	11.9
Left Plantar Flex Active (°)	60.3	10.6
Right Plantar Flex Active (°)	55.2	8.7
Left Dorsiflexion Passive (°)	13.5	4.3
Right Dorsiflexion Passive (°)	13.0	4.4
Left Dorsiflexion Active (°)	14.6	3.7
Right Dorsiflexion Active (°)	14.1	3.4
Right Straight Leg Raise (°)	89.5	9.4
Left Straight Leg Raise (°)	84.4	6.6
Right Hamstring 90/90 (°)	21.1	9.7
Left Hamstring 90/90 (°)	22.6	6.6
Left Qual Single Leg Squat (°)	2.7	1.9
Right Qual Single Leg Squat (°)	2.9	1.7
Right Ankle Knee to Wall (°)	7.5	3.2
Left Ankle Knee to Wall (°)	8.1	2.2
Left AKTW Degrees (°)	37.8	6.2
Right AKTW Degrees (°)	36.6	8.2

Table 4.3 Neuromuscular Control, Sprint, Core and Upper Limb Descriptive Statistics (N=19)

	Mean	Std. Deviation
Y Balance Post Lat Right %	91.0	9.5
Y Balance Post Lat Left %	90.0	6.3
Y Balance Post Med Right %	110.9	41.7
Y Balance Post Med Left %	106.5	32.9
Y Balance Ant Right %	129.4	39.1
Y Balance Ant Left %	132.0	22.7
5M Sprint (secs)	1.0	.06
10M Sprint (secs)	1.7	.10
20M Sprint (secs)	3.07	.21
Sport Specific Plank (min:secs)	0:03:01	0:01:08
Side Plank Right (min:secs)	0:01:27	0:00:32
Side Plank Left (min:secs)	0:01:25	0:00:40
Upper Extremity Stability Test (reps)	28.4	3.5
Unilateral Seated Shot Left 2.75Kg (m)	4.5	.71
Unilateral Seated Shot Right 2.75Kg (m)	4.7	.85
Bilateral Seated Chest Push 9Kg (m)	3.1	.33

Table 4.4 Physical Jumps and Agility Descriptive Statistics (N=19)

	Mean	Std. Deviation
Double 4 Vert Jump Height (cm)	52.4	5.6
Double 4 Vertical Jump CGT (secs)	.39	.12
Reactive Strength Index 4 Jump (RSI)	142.8	41.7
Counter Movement Jump Board (cm)	61.6	9.7
Counter Movement Jump Board Right (cm)	38.9	7.3
Counter Movement Jump Board Left (cm)	39.6	5.8
Reactive Agility Test (secs)	43.3	2.7
Non-Reactive Agility Test (secs)	46.0	5.8
Agility T-Test (secs)	10.3	.40
Yo Yo Intermittent Level 1 Test (m)	1303.1	546.2

Table 4.5 Game Statistics Descriptive Statistics (N=19)

	Mean	Std. Deviation
Number of Games Played Season Average	8.7	5.5
2pt Field Goal Percentage Season Average	34.6	18.1
3pt Field Goal Percentage Season Average	14.7	16.4
Free Throws Made Season Average	.69	.66
Free throw Percentage Season Average	49.0	34.5
Offensive Rebounds Season Average	.86	.95
Defensive Rebound Season Average	1.7	1.2
Assists Season Average	.88	.83
Steals Season Average	.85	.63
Blocked Shots Season Average	.24	.31
Total Points Season Average	4.2	3.1

Table 4.6 Injury Descriptive Statistics (N=19)

	Mean	Std. Deviation
Did athlete sustain injury (*n*)	1.1	.37
Time Loss Injuries (*n*)	.79	.91
Non-Time Loss Injuries (*n*)	.68	.58
Total Number of Injuries (*n*)	1.4	1.1

(1) Baseline Clinical Tests.

Correlations for Baseline Range of Motion upper limb group on performance outcomes using Pearson product-moment correlation (Table 4:7) showed a moderate positive correlation between height and both offensive rebounds (r = 0.54, n = 18, p < 0.05) height and blocked shots (r = 0.53, n = 18, p < 0.05). Blocked shots had moderate positive correlation with player position (r = 0.48, n = 19, p < 0.05). A moderate correlation was found between left shoulder passive internal rotation and 3pt Field Goals (r = 0.59, n = 18, p < 0.01). 2pt field goals showed moderate negative correlation with both left shoulder active internal rotation (r = -0.50, n = 18, p < 0.05) and right shoulder active internal rotation (r = -0.53, n = 18, p < 0.05). External rotation of the shoulder had consistent positive correlations with offensive rebounds, passive and active. Left shoulder passive external rotation and offensive rebounds had moderate positive correlation (r = 0.57, n = 19, p < 0.01) and right shoulder passive external rotation and offensive rebounds had strong correlation (r = 0.66, n = 19, p < 0.01). Left shoulder active external rotation had moderate positive correlation with offensive rebounds (r = 0.47, n = 18, p < 0.05) as was the right shoulder active external rotation (r < 0.56, n = 18, p < 0.05). Right shoulder passive external rotation was the only upper limb variable that showed moderate positive correlation with defensive rebounds (r = 0.46, n = 19, p < 0.05). No significant correlations were found for weight and right shoulder passive internal rotation against performance outcomes.

Correlations for Baseline Range of Motion lower limb group on performance outcomes using Pearson product-moment correlation (Table 4:8) showed moderate negative correlations between right hip passive internal rotation and number of games played (r = -0.51, n = 19, p < 0.05), total points in season (r = -0.46, n = 19, p < 0.05) and strong negative correlation with free throw percentage (r = -0.61, n = 19, p < 0.01). Left hip active internal rotation had moderate negative correlation with 2pt field goal percentage (r = -0.55, n = 18, p < 0.05). Right hip active external rotation showed moderate positive correlation with free throws (r = 0.58, n = 18, p < 0.05). Right straight leg raise had strong and moderate positive correlation with free throws (r = 0.74, n = 19, p < 0.01) and free throw percentage season respectively (r = 0.65, n = 19, p < 0.01). Right straight leg raise also had moderate positive correlation with steals season average (r = 0.56, n = 19, p < 0.05). Left straight leg raise has strong positive correlation with free throws made (r = 0.62, n = 19, p < 0.01) and moderate correlation with free throws percentage (r = 0.59, n = 19, p < 0.01). Further moderate positive correlations were found between left straight leg raise and 3pt field goal percentage (r = 0.47, n = 19, p < 0.05) and steals season average (r = 0.52, n = 19, p < 0.05). Right hamstring 90/90 test was correlated with seven performance outcomes. Strong negative correlation with free throws made (r = -0.66, n = 19, p < 0.01) and free throws percentage (r = -0.60, n = 19, p < 0.01). Moderate negative correlation between right hamstring 90/90 and number of games (r = -0.48, n = 19, p < 0.05), 3pt field goal (r = -0.45, n = 19, p < 0.05), assists season average (r = -0.47, n = 19, p < 0.05), steals season average (r = -0.55, n = 19, p < 0.05) and total point in season (r = -0.51, n = 19, p < 0.05) were found. Left hamstring 90/90 had a strong negative correlation with assists' season average (r = -0.66, n = 19, p < 0.01). No correlations were found for left hip passive internal, right hip active internal rotation, left and right hip passive external rotation and left hip active external rotation against any performance outcomes.

Correlations for ankle range of motion group on performance outcomes using Pearson product-moment correlation (Table 4:9) showed a moderate positive correlation between right plantar flexion passive and blocked shots (r = 0.55, n = 19, p < 0.05). A strong negative correlation between left dorsiflexion passive and assists (r = -0.61, n = 19, p < 0.01), also moderate negative correlations for free throws made (r = -0.50, n = 19, p < 0.05) and steals season average (r = -0.49, n = 19, p < 0.05). Right dorsi flexion passive showed eight negative correlations. Moderate negative correlations with number of games played (r = -0.58, n = 19, p < 0.01) and assists per season (r = -0.59, n = 19, p < 0.01). Strong correlation with 2pt field goal (r = -0.62, n = 19, p = 0.01) and defensive rebounds (r = -0.64, n = 19, p < 0.01). Moderate negative correlations right dorsiflexion passive and free throws made (r = -0.51, n = 19, p < 0.05), offensive rebounds (r = -0.46, n = 19, p < 0.05), steals season average (r = -0.56, n = 19, p < 0.05) and total points in season (r = -0.51, n = 19, p < 0.05). No correlations were found for left plantar flexion passive, left and right plantar flexion active, left and right dorsi flexion active on performance outcomes.

Correlations for Baseline Range of Motion upper limb group on injuries using Pearson product-moment correlation (Table 4:10) showed a moderate negative correlation between right shoulder passive internal rotation, did athlete sustain injury (r = -0.47, n = 19, p = 0.05) and non-time loss injury (r = -0.46, n = 19, p < 0.05). The only other moderate correlation for upper limb variables and injuries was right shoulder active external rotation and did athlete sustain injury ($r = 0.54$, $n = 18$, $p < 0.05$).

Correlations for Range of Motion lower limb group on injuries using Pearson product-moment correlation (Table 4:11) showed a strong positive correlation between right hip passive external rotation and did athlete sustain injury ($r = 0.70$, $n = 19$, $p < 0.01$). A moderate negative correlation between left hamstring 90/90 and non-time-loss injury ($r = -0.58$, $n = 19$, $p < 0.01$) was found and one final moderate negative correlation in this group between left hip active external rotation and time-loss injury ($r = -0.48$, $n = 18$, $p < 0.05$). No further correlations were found between lower limb group and injuries.

Correlations for ankle Range of Motion group on injuries using Pearson product-moment correlation (Table 4:12) showed strong correlation between both left plantar flexion active ($r = 0.65$, $n = 18$, $p < 0.01$) and a moderate correlation with right plantar flexion active ($r = 0.59$, $n = 18$, $p < 0.01$) with did athlete sustain injury. A moderate negative correlation was found between right plantar flexion active and total number of injuries ($r = -0.47$, $n = 18$, $p < 0.05$). No further correlations were found between ankle range of motion variables and injuries.

Table 4.7 Baseline and ROM Upper Limb Correlations with Game Performance Outcomes

		Height in cm	Weight in Kg	Left Shoulder Passive Int Rot	Right Shoulder Passive Int Rot	Left Shoulder Active Int Rot	Right Shoulder Active Int Rot	Left Shoulder Passive Ext Rot	Right Shoulder Passive Ext Rot	Left Shoulder Active Ext Rot	Right Shoulder Active Ext Rot
Number of Games Played Season Average	Pearson Correlation	.340	.249	.407	.052	-.163	-.169	.306	.282	.061	-.039
	Sig. (2-tailed)	.167	.319	.084	.833	.517	.504	.202	.242	.810	.877
	N	18	18	19	19	18	18	19	19	18	18
2pt Field Goal Percentage Season Average	Pearson Correlation	.106	.333	-.201	-.448	-.500*	-.538*	.250	.351	.022	.087
	Sig. (2-tailed)	.675	.177	.409	.054	.035	.021	.303	.141	.931	.731
	N	18	18	19	19	18	18	19	19	18	18
3pt Field Goal Percentage Season Average	Pearson Correlation	-.126	-.018	.593**	.222	.109	.106	-.007	.023	-.372	-.226
	Sig. (2-tailed)	.617	.944	.007	.360	.665	.675	.977	.926	.128	.367
	N	18	18	19	19	18	18	19	19	18	18
Free Throws Made Season Average	Pearson Correlation	.034	.056	-.024	-.147	-.089	-.218	.356	.316	.109	.260
	Sig. (2-tailed)	.893	.825	.922	.547	.725	.384	.135	.188	.667	.298
	N	18	18	19	19	18	18	19	19	18	18
Free throw Percentage Season Average	Pearson Correlation	.073	.149	.036	-.105	-.154	-.126	.318	.222	.113	.022
	Sig. (2-tailed)	.774	.556	.883	.667	.543	.618	.184	.362	.656	.932
	N	18	18	19	19	18	18	19	19	18	18
Offensive Rebounds Season Average	Pearson Correlation	.541*	.365	-.027	-.409	-.283	-.460	.575**	.667**	.473*	.566*
	Sig. (2-tailed)	.020	.137	.914	.082	.256	.055	.010	.002	.048	.014
	N	18	18	19	19	18	18	19	19	18	18
Deffensive Rebound Season Average	Pearson Correlation	.197	.315	.306	-.079	-.197	-.295	.369	.462*	-.032	.122
	Sig. (2-tailed)	.433	.203	.202	.749	.434	.235	.121	.047	.899	.630
	N	18	18	19	19	18	18	19	19	18	18
Assists Season Average	Pearson Correlation	-.121	-.031	.010	.189	-.255	-.197	.171	.070	-.030	-.152
	Sig. (2-tailed)	.634	.903	.969	.438	.307	.433	.483	.776	.906	.546
	N	18	18	19	19	18	18	19	19	18	18
Steals Season Average	Pearson Correlation	-.296	.028	.120	.281	-.122	.012	.175	.021	-.116	-.261
	Sig. (2-tailed)	.233	.912	.625	.244	.629	.962	.474	.932	.647	.296
	N	18	18	19	19	18	18	19	19	18	18
Blocked Shots Season Average	Pearson Correlation	.534*	.386	.211	-.211	-.043	-.151	.461*	.418	.181	.380
	Sig. (2-tailed)	.022	.113	.386	.385	.866	.548	.047	.075	.472	.120
	N	18	18	19	19	18	18	19	19	18	18
Total Points Season Average	Pearson Correlation	.156	.036	.147	-.132	-.100	-.284	.199	.319	-.085	.137
	Sig. (2-tailed)	.537	.887	.548	.589	.693	.253	.413	.183	.738	.588
	N	18	18	19	19	18	18	19	19	18	18

In this table * = Correlation is significant at the 0.05 level (2-tailed) and ** = Correlation is significant at the 0.01 level (2-tailed).

Table 4.8 Range of Motion Lower Limb Correlations with Game Performance Outcomes.

		Left Hip Passive Int Rot	Right Hip Passive Int Rot	Left Hip Active Int Rot	Right Hip Active Int Rot	Left Hip Passive Ext Rot	Right Hip Passive Ext Rot	Left Hip Active Ext Rot	Right Hip Active Ext Rot	Right Straight Leg Raise	Left Straight Leg Raise	Right Hamstring 90/90	Left Hamstring 90/90
Number of Games Played	Pearson Correlation	-.337	**-.512***	-.184	-.328	.246	-.005	-.176	.126	.334	.448	**-.482***	-.326
	Sig. (2-tailed)	.159	.025	.466	.184	.310	.985	.486	.618	.162	.054	.037	.173
	N	19	19	18	18	19	19	18	18	19	19	19	19
2pt Field Goal Percentag	Pearson Correlation	-.408	-.395	**-.555***	-.317	.064	.053	-.173	.008	.248	.204	-.359	-.103
	Sig. (2-tailed)	.083	.094	.017	.201	.794	.830	.492	.976	.306	.403	.131	.676
	N	19	19	18	18	19	19	18	18	19	19	19	19
3pt Field Goal Percentag	Pearson Correlation	-.234	-.358	-.045	-.213	-.042	-.076	-.181	-.050	.376	**.475***	**-.457***	-.390
	Sig. (2-tailed)	.334	.132	.858	.396	.866	.757	.472	.844	.113	.040	.049	.099
	N	19	19	18	18	19	19	18	18	19	19	19	19
Free Throws Made	Pearson Correlation	-.012	-.448	-.228	-.146	.124	.260	.173	**.580***	**.740****	**.621****	**-.669****	-.372
	Sig. (2-tailed)	.961	.054	.362	.562	.613	.282	.493	.012	.000	.005	.002	.117
	N	19	19	18	18	19	19	18	18	19	19	19	19
Free throw Percentag e Season	Pearson Correlation	-.426	**-.612****	-.351	-.287	.176	.073	.155	.372	**.654****	**.598****	**-.602****	-.142
	Sig. (2-tailed)	.069	.005	.153	.249	.472	.765	.539	.129	.002	.007	.006	.563
	N	19	19	18	18	19	19	18	18	19	19	19	19
Offensive Rebounds Season	Pearson Correlation	.117	-.364	-.308	-.191	.290	.272	.102	.263	.258	.248	-.302	-.088
	Sig. (2-tailed)	.633	.126	.214	.447	.228	.261	.687	.292	.285	.305	.210	.721
	N	19	19	18	18	19	19	18	18	19	19	19	19
Deffensive Rebound Season	Pearson Correlation	-.245	-.414	-.138	-.216	.031	-.068	-.332	-.041	.227	.279	-.320	-.363
	Sig. (2-tailed)	.313	.078	.584	.389	.901	.782	.178	.872	.349	.247	.181	.126
	N	19	19	18	18	19	19	18	18	19	19	19	19
Assists Season Average	Pearson Correlation	-.114	.014	.092	.070	.074	-.038	-.175	.195	.324	.309	**-.476***	**-.665****
	Sig. (2-tailed)	.642	.956	.718	.783	.763	.878	.488	.439	.177	.198	.039	.002
	N	19	19	18	18	19	19	18	18	19	19	19	19
Steals Season Average	Pearson Correlation	-.382	-.285	-.191	-.086	.020	-.037	-.062	.106	**.561***	**.525***	**-.557***	-.444
	Sig. (2-tailed)	.107	.237	.447	.734	.937	.881	.806	.674	.013	.021	.013	.057
	N	19	19	18	18	19	19	18	18	19	19	19	19
Blocked Shots Season	Pearson Correlation	-.202	-.540*	-.465	-.324	.246	.107	.237	.248	.388	.294	-.162	.014
	Sig. (2-tailed)	.406	.017	.052	.190	.309	.662	.345	.322	.101	.222	.506	.955
	N	19	19	18	18	19	19	18	18	19	19	19	19
Total Points Season	Pearson Correlation	-.037	**-.463***	-.102	-.227	-.082	.219	-.367	.323	.416	.426	**-.518***	-.299
	Sig. (2-tailed)	.880	.046	.687	.366	.739	.368	.135	.191	.077	.069	.023	.214
	N	19	19	18	18	19	19	18	18	19	19	19	19

In this table *. Correlation is significant at the 0.05 level (2-tailed) and **. Correlation is significant at the 0.01 level (2-tailed).

Table 4.9 Ankle Range of Motion Correlations with Game Performance Outcomes.

		Left Plantar Flex Passive	Right Plantar Flex Passive	Left Plantar Flex Active	Right Plantar Flex Active	Left Dorsiflexion Passive	Right Dorsiflexion Passive	Left Dorsiflexion Active	Right Dorsiflexion Active
Number of Games Played	Pearson Correlation	.136	.349	-.080	.147	-.412	-.584**	-.266	-.382
	Sig. (2-tailed)	.580	.143	.751	.560	.080	.009	.285	.117
	N	19	19	18	18	19	19	18	18
2pt Field Goal Percentag	Pearson Correlation	.101	.078	-.015	.080	-.332	-.624**	-.124	-.122
	Sig. (2-tailed)	.680	.750	.953	.752	.165	.004	.624	.628
	N	19	19	18	18	19	19	18	18
3pt Field Goal Percentag	Pearson Correlation	-.124	-.059	-.282	-.145	-.289	-.330	-.214	-.046
	Sig. (2-tailed)	.614	.810	.258	.567	.231	.168	.394	.856
	N	19	19	18	18	19	19	18	18
Free Throws Made	Pearson Correlation	.319	.199	-.072	-.179	-.507*	-.515*	-.443	-.156
	Sig. (2-tailed)	.183	.415	.776	.476	.027	.024	.066	.536
	N	19	19	18	18	19	19	18	18
Free throw Percentage Season	Pearson Correlation	.301	.217	.257	.205	-.321	-.415	-.288	-.009
	Sig. (2-tailed)	.210	.373	.302	.415	.180	.078	.246	.972
	N	19	19	18	18	19	19	18	18
Offensive Rebounds Season	Pearson Correlation	.330	.446	.045	.133	-.211	-.461*	-.017	-.126
	Sig. (2-tailed)	.168	.056	.859	.597	.387	.047	.947	.617
	N	19	19	18	18	19	19	18	18
Deffensive Rebound Season	Pearson Correlation	.139	.188	-.183	-.009	-.423	-.642**	.014	-.148
	Sig. (2-tailed)	.570	.440	.467	.971	.071	.003	.956	.558
	N	19	19	18	18	19	19	18	18
Assists Season Average	Pearson Correlation	.132	-.087	-.333	-.197	-.618**	-.597**	-.240	-.372
	Sig. (2-tailed)	.590	.724	.177	.432	.005	.007	.337	.129
	N	19	19	18	18	19	19	18	18
Steals Season Average	Pearson Correlation	.087	-.176	-.106	-.107	-.496*	-.569*	-.273	-.154
	Sig. (2-tailed)	.723	.471	.674	.673	.031	.011	.273	.542
	N	19	19	18	18	19	19	18	18
Blocked Shots Season	Pearson Correlation	.232	.553*	-.082	.028	-.029	-.227	-.067	.011
	Sig. (2-tailed)	.338	.014	.746	.913	.908	.350	.793	.966
	N	19	19	18	18	19	19	18	18
Total Points Season	Pearson Correlation	.137	.209	-.050	-.004	-.382	-.510*	-.211	-.246
	Sig. (2-tailed)	.576	.390	.843	.988	.106	.026	.400	.326
	N	19	19	18	18	19	19	18	18

In this table *. Correlation is significant at the 0.05 level (2-tailed) and **. Correlation is significant at the 0.01 level (2-tailed).

Table 4.10 Baseline Range of Motion Correlations with Injuries

		Height in cm	Weight in Kg	Player position	Left Shoulder Passive Int Rot	Right Shoulder Passive Int Rot	Left Shoulder Active Int Rot	Right Shoulder Active Int Rot	Left Shoulder Passive Ext Rot	Right Shoulder Passive Ext Rot	Left Shoulder Active Ext Rot	Right Shoulder Active Ext Rot
Did athlete sustain injury	Pearson Correlation	.228	-.033	.224	-.381	-.477*	-.314	-.389	.148	.396	.464	**.540***
	Sig. (2-tailed)	.363	.896	.357	.108	.039	.204	.111	.544	.094	.053	.021
	N	18	18	19	19	19	18	18	19	19	18	18
Time Loss Injuries	Pearson Correlation	-.390	-.104	-.339	-.112	.044	.207	.085	-.227	-.183	-.164	-.171
	Sig. (2-tailed)	.110	.682	.156	.649	.859	.409	.736	.349	.454	.515	.496
	N	18	18	19	19	19	18	18	19	19	18	18
Non-Time Loss Injuries	Pearson Correlation	-.265	-.042	-.174	.253	**.465***	-.070	.097	.121	-.122	-.361	-.432
	Sig. (2-tailed)	.288	.869	.477	.297	.045	.783	.701	.622	.618	.141	.073
	N	18	18	19	19	19	18	18	19	19	18	18
Total Number of Injuries	Pearson Correlation	-.467	-.109	-.366	.040	.277	.138	.123	-.123	-.213	-.327	-.371
	Sig. (2-tailed)	.051	.666	.123	.872	.252	.585	.627	.616	.382	.185	.130
	N	18	18	19	19	19	18	18	19	19	18	18

In this table *. Correlation is significant at the 0.05 level (2-tailed) and **. Correlation is significant at the 0.01 level (2-tailed).

Table 4.11 Range of Motion Lower Limb Correlations with Injuries.

		Left Hip Passive Int Rot	Right Hip Passive Int Rot	Left Hip Active Int Rot	Right Hip Active Int Rot	Left Hip Passive Ext Rot	Right Hip Passive Ext Rot	Left Hip Active Ext Rot	Right Hip Active Ext Rot	Right Straight Leg Raise	Left Straight Leg Raise	Right Hamstring 90/90	Left Hamstring 90/90
Did athlete sustain injury	Pearson Correlation	.432	.187	.034	-.041	.330	**.701****	.294	.419	.086	.192	-.251	.044
	Sig. (2-tailed)	.065	.444	.892	.873	.167	.001	.237	.084	.728	.431	.300	.860
	N	19	19	18	18	19	19	18	18	19	19	19	19
Time Loss Injuries	Pearson Correlation	-.179	-.317	-.072	-.032	-.328	-.188	**-.483***	.061	.104	-.010	-.108	.071
	Sig. (2-tailed)	.463	.186	.776	.900	.170	.441	.043	.810	.673	.967	.660	.774
	N	19	19	18	18	19	19	18	18	19	19	19	19
Non-Time Loss Injuries	Pearson Correlation	-.101	.074	.058	.169	-.155	-.170	.019	-.064	.438	.430	-.353	**-.588****
	Sig. (2-tailed)	.681	.763	.819	.504	.527	.487	.941	.800	.061	.066	.138	.008
	N	19	19	18	18	19	19	18	18	19	19	19	19
Total Number of Injuries	Pearson Correlation	-.199	-.220	-.030	.061	-.348	-.241	-.397	.018	.312	.215	-.271	-.247
	Sig. (2-tailed)	.415	.365	.905	.809	.144	.319	.103	.944	.194	.378	.261	.308
	N	19	19	18	18	19	19	18	18	19	19	19	19

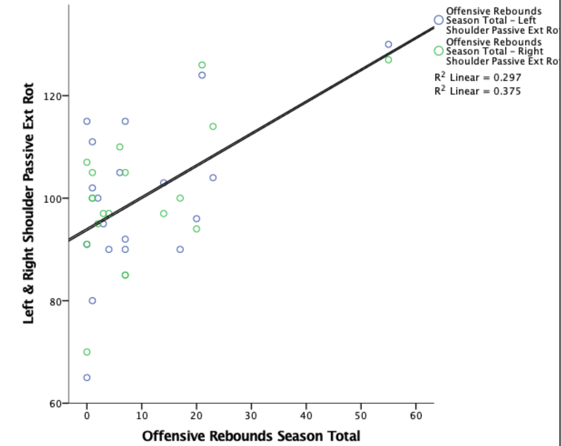
In this table *. Correlation is significant at the 0.05 level (2-tailed) and **. Correlation is significant at the 0.01 level (2-tailed).

Table 4.12 Ankle Range of Motion Correlations with Injuries.

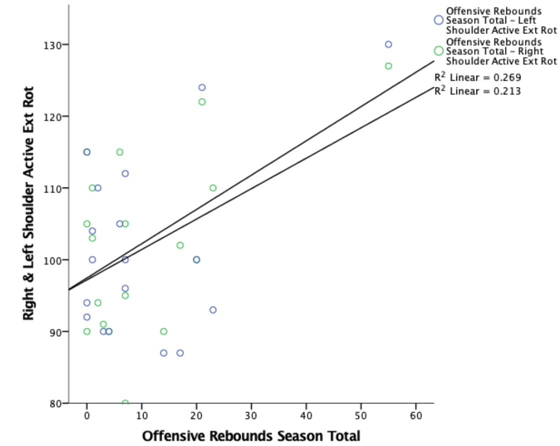
		Left Plantar Flex Passive	Right Plantar Flex Passive	Left Plantar Flex Active	Right Plantar Flex Active	Left Dorsiflexion Passive	Right Dorsiflexion Passive	Left Dorsiflexion Active	Right Dorsiflexion Active
Did athlete sustain injury	Pearson Correlation	.389	.089	**.655****	**.596****	-.025	-.200	-.011	-.064
	Sig. (2-tailed)	.099	.716	.003	.009	.919	.413	.966	.800
	N	19	19	18	18	19	19	18	18
Time Loss Injuries	Pearson Correlation	-.317	-.207	-.233	-.317	-.230	-.109	-.054	.098
	Sig. (2-tailed)	.185	.394	.351	.200	.343	.658	.833	.699
	N	19	19	18	18	19	19	18	18
Non-Time Loss Injuries	Pearson Correlation	-.003	-.347	-.321	-.398	-.316	-.171	-.244	-.220
	Sig. (2-tailed)	.991	.146	.195	.102	.188	.484	.330	.380
	N	19	19	18	18	19	19	18	18
Total Number of Injuries	Pearson Correlation	-.261	-.349	-.365	**-.475***	-.352	-.177	-.173	-.033
	Sig. (2-tailed)	.281	.143	.137	.046	.140	.468	.493	.897
	N	19	19	18	18	19	19	18	18

In this table *. Correlation is significant at the 0.05 level (2-tailed) and **. Correlation is significant at the 0.01 level (2-tailed).

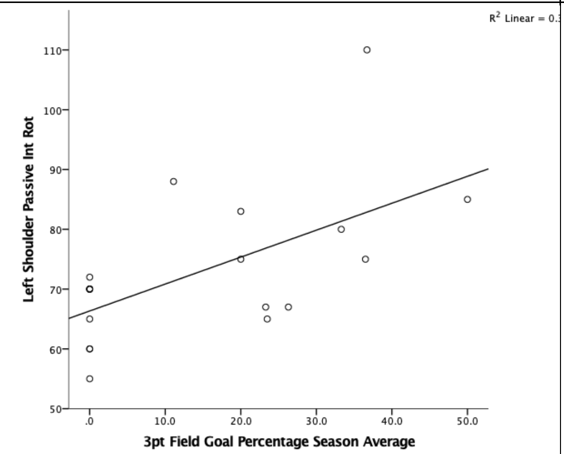
Table 4.13 Selected Upper Limb and Performance Outcome Associations Scatter Plots.



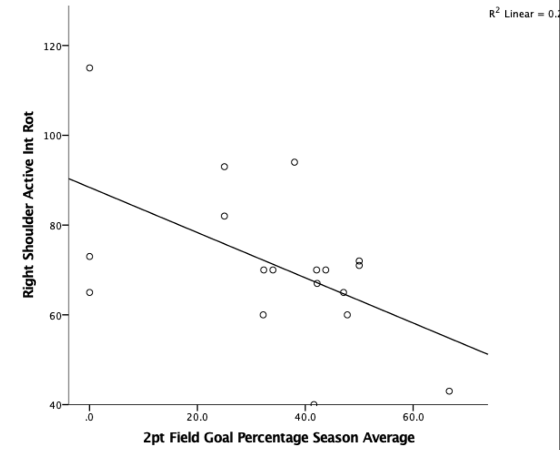
This scatter plot shows a moderate, positive, linear association between both left and right shoulder passive external rotation and offensive rebounds.



This scatter plot shows a moderate, positive, linear association between both left and right shoulder active external rotation and offensive rebounds.

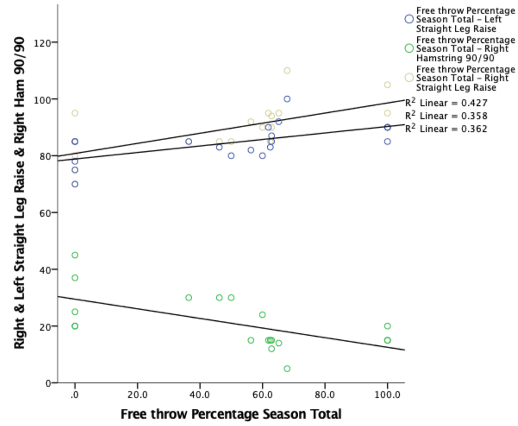


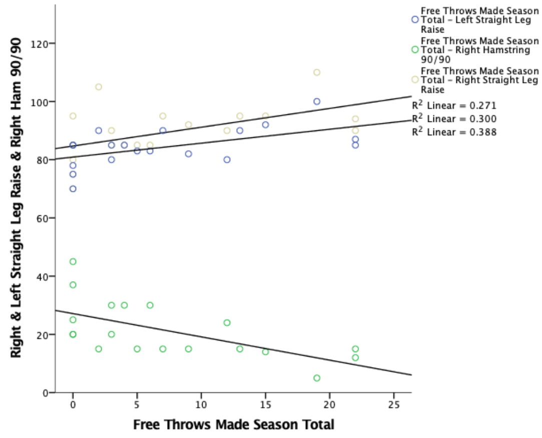
This scatter plot shows a moderate, positive, linear association between left shoulder passive internal rotation and 3pt field goal percentage season average.

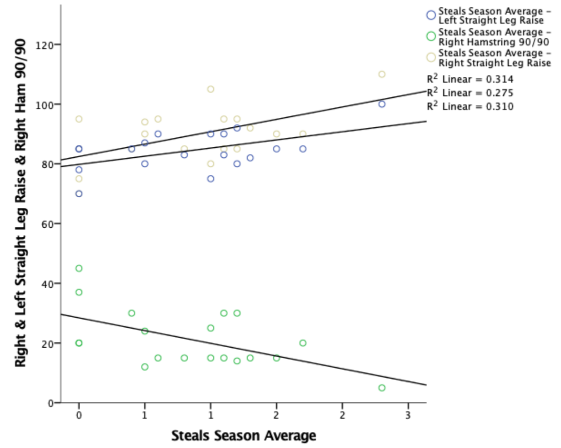


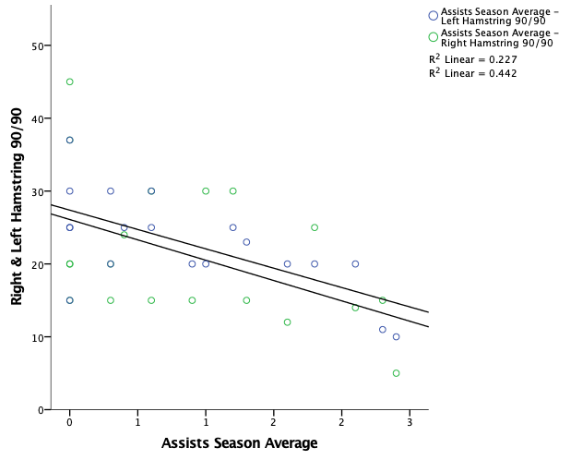
This scatter plot shows a moderate, negative, linear association between both right shoulder active internal rotation and 2pt field goal percentage season average.

Table 4.14 Selected Lower Limb and Performance Outcome Associations Scatter Plots.

<table>
<tr>
<td>


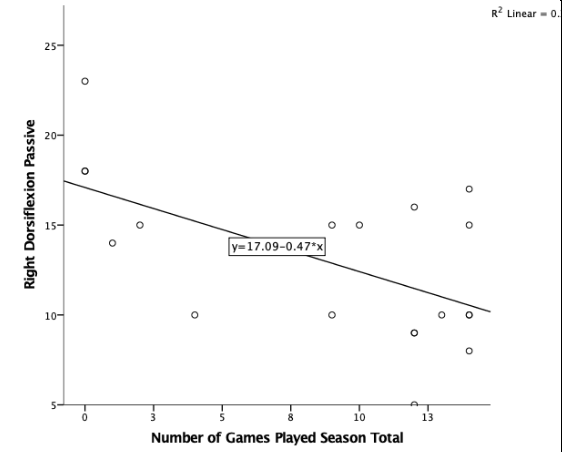
This scatter plot shows a moderate, positive, linear association between both left and right straight leg raise and free throw percentage season average. Moderate, negative, linear association between right hamstring 90/90 and free throw percentage season average.
</td>
<td>


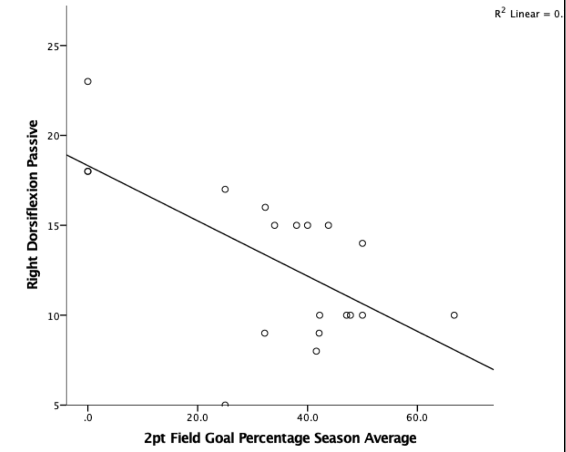
This scatter plot shows a moderate, positive, linear association between both left and right straight leg raise and free throw percentage season average. Moderate, negative, linear association between right hamstring 90/90 and free throws made season average.
</td>
</tr>
<tr>
<td>


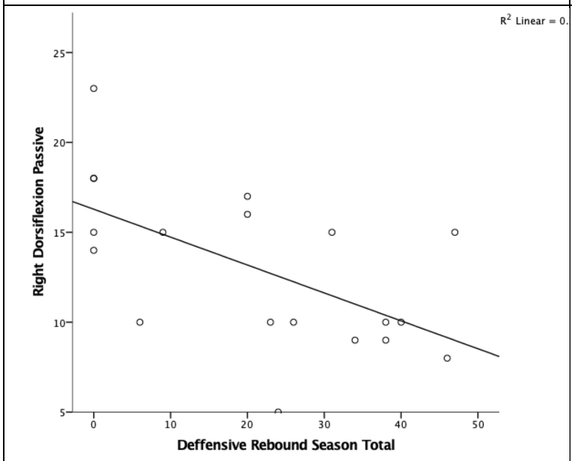
This scatter plot shows a moderate, positive, linear association between both left and right straight leg raise and free throw percentage season average. Moderate, negative, linear association between right hamstring 90/90 and steals season average.
</td>
<td>


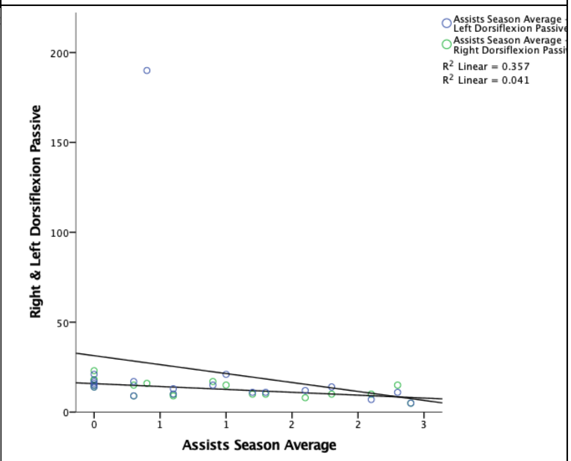
This scatter plot shows a moderate, negative, linear association between both right and left hamstring 90/90 and assists season average.
</td>
</tr>
</table>

Table 4.15 Selected Ankle ROM and Performance Outcome Associations Scatter Plots.

<table>
<tr>
<td>


This scatter plot shows a moderate, negative, linear association between right dorsiflexion passive and number of games played season total.
</td>
<td>


This scatter plot shows a moderate to strong, negative, linear association between right dorsiflexion passive and 2pt field goal percentage season average.
</td>
</tr>
<tr>
<td>


This scatter plot shows a moderate to strong, negative, linear association between right dorsiflexion passive and defensive rebound season total.
</td>
<td>


This scatter plot shows a low to moderate, negative, linear association between left and right dorsiflexion passive and assists season average.
</td>
</tr>
</table>

(2) Neuromuscular Tests

Correlations for neuromuscular and balance group on performance outcomes using Pearson product-moment correlation (Table 4:13) showed strong positive correlation between left qualitative single leg squat and free throws made (r = 0.62, n = 18, p < 0.01) and offensive rebounds (r = 0.61, n = 18, p < 0.01). Positive moderate correlation was also found between right qualitative single leg squat and free throws made (r = 0.51, n = 18, p < 0.05) and offensive rebounds (r = 0.47, n = 18, p < 0.05). Offensive rebounds are also moderately negatively correlated with left AKTW (r = -0.47, n = 18, p < 0.05) and defensive rebounds moderately negatively correlated with right AKTW (r = -0.59, n = 18, p < 0.01). Y Balance posterior media right percentage has a moderate negative correlation with number of games played season average (r = -0.50, n = 18, p < 0.05) and free throw percentage season average (r = -0.58, n = 18, p < 0.05). Moderate negative correlation between Y Balance posterior medial left and free throw percentage season average was found (r = -0.53, n = 18, p < 0.05). No further correlations were detected between neuromuscular and balance group and performance outcomes.

Table 4.16 Neuromuscular and Balance Correlations with Game Performance Outcomes.

		Left Qual Single Leg Squat	Right Qual Single Leg Squat	Right Ankle Knee to Wall	Left Ankle Knee to Wall	Left AKTW Degrees	Right AKTW Degrees	Y Balance Post Lat Right %	Y Balance Post Lat Left %	Y Balance Post Med Right %	Y Balance Post Med Left %	Y Balance Ant Right %	Y Blaance Ant Left %
Number of Games Played Season Average	Pearson Correlation	.143	-.017	-.017	-.045	-.300	-.449	.101	-.188	-.504*	-.457	-.375	-.169
	Sig. (2-tailed)	.571	.946	.948	.860	.226	.062	.689	.456	.033	.056	.125	.502
	N	18	18	18	18	18	18	18	18	18	18	18	18
2pt Field Goal Percentage Season Average	Pearson Correlation	-.126	-.231	-.096	.092	-.298	-.313	.163	-.096	-.053	-.008	-.088	.001
	Sig. (2-tailed)	.618	.356	.704	.717	.230	.206	.518	.706	.834	.976	.729	.997
	N	18	18	18	18	18	18	18	18	18	18	18	18
3pt Field Goal Percentage Season Average	Pearson Correlation	.227	.162	.053	-.281	.014	-.110	.244	.162	-.335	-.299	-.401	-.458
	Sig. (2-tailed)	.365	.521	.834	.258	.956	.665	.329	.521	.175	.228	.099	.056
	N	18	18	18	18	18	18	18	18	18	18	18	18
Free Throws Made Season Average	Pearson Correlation	.620**	.517*	-.141	-.224	-.301	-.119	.325	.290	-.308	-.248	.045	-.269
	Sig. (2-tailed)	.006	.028	.576	.371	.225	.638	.189	.242	.214	.321	.858	.280
	N	18	18	18	18	18	18	18	18	18	18	18	18
Free throw Percentage Season Average	Pearson Correlation	.105	.084	.089	.141	-.196	-.089	.209	-.107	-.580*	-.536*	-.241	-.074
	Sig. (2-tailed)	.677	.741	.725	.576	.435	.725	.406	.673	.012	.022	.336	.769
	N	18	18	18	18	18	18	18	18	18	18	18	18
Offensive Rebounds Season Average	Pearson Correlation	.614**	.479*	-.191	-.191	-.476*	-.452	-.003	.056	-.225	-.236	-.193	-.454
	Sig. (2-tailed)	.007	.044	.448	.447	.046	.060	.991	.825	.369	.345	.442	.058
	N	18	18	18	18	18	18	18	18	18	18	18	18
Deffensive Rebound Season Average	Pearson Correlation	.345	.157	-.165	-.293	-.401	-.595**	.181	-.085	-.346	-.325	-.452	-.372
	Sig. (2-tailed)	.161	.534	.513	.238	.100	.009	.472	.737	.160	.189	.060	.128
	N	18	18	18	18	18	18	18	18	18	18	18	18
Assists Season Average	Pearson Correlation	.156	.132	-.268	-.200	-.226	-.118	.053	-.250	-.038	.104	-.006	.028
	Sig. (2-tailed)	.536	.601	.283	.426	.368	.642	.836	.317	.883	.682	.980	.911
	N	18	18	18	18	18	18	18	18	18	18	18	18
Steals Season Average	Pearson Correlation	-.019	-.026	-.047	.032	.011	.039	.214	-.185	-.269	-.162	-.025	.072
	Sig. (2-tailed)	.940	.917	.852	.899	.967	.877	.395	.463	.280	.521	.921	.776
	N	18	18	18	18	18	18	18	18	18	18	18	18
Blocked Shots Season Average	Pearson Correlation	.461	.274	.055	.040	-.260	-.261	.212	.426	-.175	-.225	.132	-.222
	Sig. (2-tailed)	.054	.272	.829	.876	.298	.295	.399	.078	.486	.369	.602	.376
	N	18	18	18	18	18	18	18	18	18	18	18	18
Total Points Season Average	Pearson Correlation	.383	.189	-.182	-.307	-.304	-.368	.072	.083	-.417	-.377	-.221	-.215
	Sig. (2-tailed)	.117	.453	.469	.216	.220	.133	.776	.743	.085	.123	.379	.391
	N	18	18	18	18	18	18	18	18	18	18	18	18

In this table *. Correlation is significant at the 0.05 level (2-tailed) and **. Correlation is significant at the 0.01 level (2-tailed).

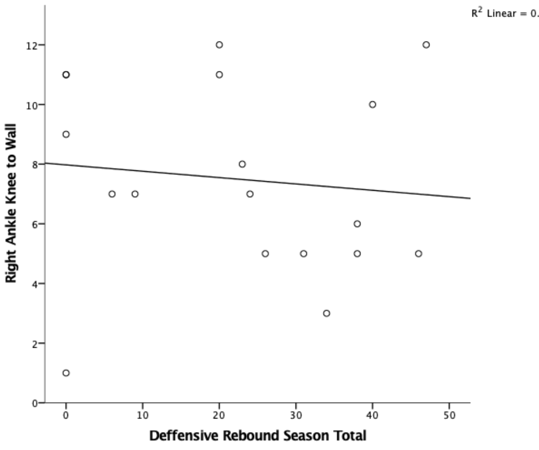
Table 4.17 Neuromuscular and Balance Correlations with Injuries.

		Left Qual Single Leg Squat	Right Qual Single Leg Squat	Right Ankle Knee to Wall	Left Ankle Knee to Wall	Left AKTW Degrees	Right AKTW Degrees	Y Balance Post Lat Right %	Y Balance Post Lat Left %	Y Balance Post Med Right %	Y Balance Post Med Left %	Y Balance Ant Right %	Y Blaance Ant Left %
Did athlete sustain injury	Pearson Correlation	.142	.112	0.000	-.023	-.165	-.027	-.403	-.385	-.207	-.181	**-.683****	-.322
	Sig. (2-tailed)	.574	.657	1.000	.929	.513	.915	.098	.115	.409	.472	.002	.192
	N	18	18	18	18	18	18	18	18	18	18	18	18
Time Loss Injuries	Pearson Correlation	.069	.030	-.208	-.146	-.117	-.195	.301	.096	-.116	-.111	.399	.317
	Sig. (2-tailed)	.785	.907	.409	.564	.643	.438	.225	.704	.646	.661	.101	.199
	N	18	18	18	18	18	18	18	18	18	18	18	18
Non-Time Loss Injuries	Pearson Correlation	.083	.212	-.143	-.175	.134	.300	.200	.123	-.095	.003	.215	-.065
	Sig. (2-tailed)	.744	.398	.571	.486	.597	.227	.427	.626	.709	.992	.392	.799
	N	18	18	18	18	18	18	18	18	18	18	18	18
Total Number of Injuries	Pearson Correlation	.102	.136	-.250	-.215	-.029	-.007	.358	.146	-.147	-.092	.449	.233
	Sig. (2-tailed)	.688	.591	.318	.392	.910	.977	.144	.564	.559	.716	.062	.351
	N	18	18	18	18	18	18	18	18	18	18	18	18

In this table *. Correlation is significant at the 0.05 level (2-tailed) and **. Correlation is significant at the 0.01 level (2-tailed).

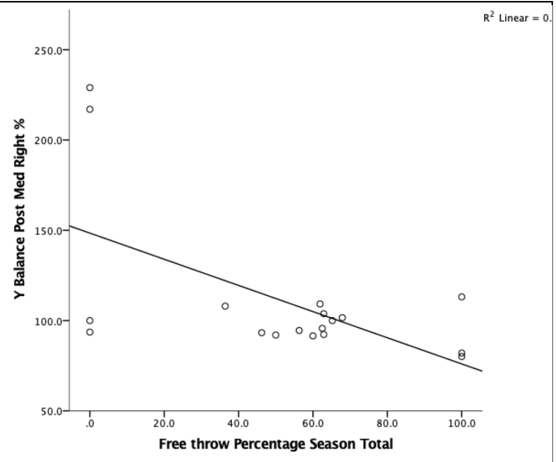
Table 4.18 Selected Neuromuscular Tests and Performance Outcome Associations Scatter Plots.

<table>
<tr>
<td>



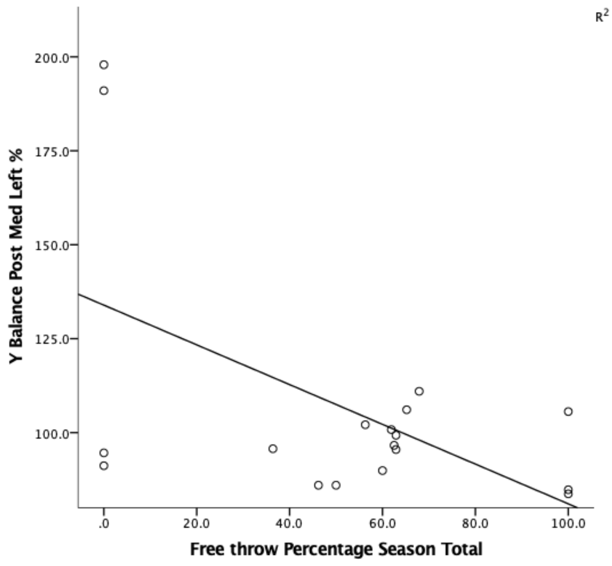
This scatter plot shows a weak to moderate, negative, non-linear association between right ankle knee to wall and defensive rebounds season total.

</td>
<td>



This scatter plot shows a moderate, negative, linear association between Y balance post med right and free throw percentage season average.

</td>
</tr>
<tr>
<td colspan="2">



This scatter plot shows a moderate, negative, linear association between Y balance post med left and free throw percentage season average.

</td>
</tr>
</table>

(3) Comparative Upper Limb and Physical Tests + CKCUEST

Correlations for upper limb physical tests group on performance outcomes using Pearson product-moment correlation (Table 4:15) showed moderate positive correlations between unilateral seated shot left and number of games season average (r = 0.53, n = 18, p < 0.05), blocked shots season average (r = 0.52, n = 18, p < 0.05) and total points season average (r = 0.48, n = 18, p < 0.05). Moderate positive correlations were found between bilateral seated chest push 9Kg and number of games played season average (r = 0.48, n = 18, p < 0.05) and also free throw percentage season average (r = 0.52, n = 18, p < 0.05). No correlation was found between unilateral seated shot right and performance outcomes.

No correlations for upper limb physical tests group and injuries were found (Table 4:16).

Table 4.19 Upper Limb Physical Tests Correlation with Game Performance Outcomes.

		Unilateral Seated Shot Left 2.75Kg	Unilateral Seated Shot Right 2.75Kg	Bilateral Seated Chest Push 9Kg
Number of Games Played Season Average	Pearson Correlation	**.533***	.338	**.488***
	Sig. (2-tailed)	.023	.170	.040
	N	18	18	18
2pt Field Goal Percentage Season Average	Pearson Correlation	.290	.250	.329
	Sig. (2-tailed)	.242	.316	.183
	N	18	18	18
3pt Field Goal Percentage Season Average	Pearson Correlation	.349	.184	.413
	Sig. (2-tailed)	.156	.466	.088
	N	18	18	18
Free Throws Made Season Average	Pearson Correlation	.403	.066	.265
	Sig. (2-tailed)	.097	.794	.287
	N	18	18	18
Free throw Percentage Season Average	Pearson Correlation	.242	.100	**.522***
	Sig. (2-tailed)	.334	.692	.026
	N	18	18	18
Offensive Rebounds Season Average	Pearson Correlation	.451	.337	.359
	Sig. (2-tailed)	.060	.171	.143
	N	18	18	18
Deffensive Rebound Season Average	Pearson Correlation	.347	.250	.467
	Sig. (2-tailed)	.158	.316	.051
	N	18	18	18
Assists Season Average	Pearson Correlation	.218	-.165	-.035
	Sig. (2-tailed)	.386	.514	.889
	N	18	18	18
Steals Season Average	Pearson Correlation	.079	-.281	.137
	Sig. (2-tailed)	.757	.259	.588
	N	18	18	18
Blocked Shots Season Average	Pearson Correlation	**.527***	.458	.357
	Sig. (2-tailed)	.025	.056	.145
	N	18	18	18
Total Points Season Average	Pearson Correlation	**.487***	.288	.390
	Sig. (2-tailed)	.040	.246	.110
	N	18	18	18

In this table *. Correlation is significant at the 0.05 level (2-tailed) and **. Correlation is significant at the 0.01 level (2-tailed).

Table 4.20 Upper Limb Physical Tests Correlation with Injuries.

		Unilateral Seated Shot Left 2.75Kg	Unilateral Seated Shot Right 2.75Kg	Bilateral Seated Chest Push 9Kg
Did athlete sustain injury	Pearson Correlation	-.070	.008	.154
	Sig. (2-tailed)	.784	.975	.542
	N	18	18	18
Time Loss Injuries	Pearson Correlation	-.088	-.185	-.024
	Sig. (2-tailed)	.727	.462	.924
	N	18	18	18
Non-Time Loss Injuries	Pearson Correlation	.161	-.252	-.054
	Sig. (2-tailed)	.524	.314	.831
	N	18	18	18
Total Number of Injuries	Pearson Correlation	.010	-.288	-.049
	Sig. (2-tailed)	.969	.247	.848
	N	18	18	18

In this table *. Correlation is significant at the 0.05 level (2-tailed) and **. Correlation is significant at the 0.01 level (2-tailed).

(4) Strength Endurance and Stability

Correlations for core strength endurance and stability group on performance outcomes using Pearson product-moment correlation (Table 4:17) showed strong negative correlation between side plank left and both defensive rebound season average (r = -0.70, n = 18, p < 0.01) and moderate correlation for assists season average (r = -0.59, n = 18, p < 0.01). Side plank left also had moderate negative correlation with 2pt field goal (r = -0.48, n = 18, p < 0.05). Upper extremity stability test showed moderate positive correlation with 3pt field goal (r = 0.55, n = 18, p < 0.05). No correlation was found between sport specific side plank, side plank right and the performance outcomes.

No significant correlations were found between core strength endurance and stability group and injuries (Table 4:18).

Table 4.21 Core Strength Endurance and Stability Correlations with Game Performance Outcomes.

		Sport Specific Plank	Side Plank Right	Side Plank Left	Upper Extremity Stability Test
Number of Games Played Season Average	Pearson Correlation	.285	-.142	-.376	.210
	Sig. (2-tailed)	.252	.575	.124	.403
	N	18	18	18	18
2pt Field Goal Percentage Season Average	Pearson Correlation	.379	-.364	**-.489***	.170
	Sig. (2-tailed)	.121	.137	.040	.501
	N	18	18	18	18
3pt Field Goal Percentage Season Average	Pearson Correlation	.314	.022	-.253	**.550***
	Sig. (2-tailed)	.204	.931	.311	.018
	N	18	18	18	18
Free Throws Made Season Average	Pearson Correlation	-.144	-.227	-.302	.231
	Sig. (2-tailed)	.569	.366	.224	.356
	N	18	18	18	18
Free throw Percentage Season Average	Pearson Correlation	.376	.036	-.124	.225
	Sig. (2-tailed)	.124	.888	.624	.370
	N	18	18	18	18
Offensive Rebounds Season Average	Pearson Correlation	-.344	-.361	-.378	-.070
	Sig. (2-tailed)	.162	.141	.122	.783
	N	18	18	18	18
Deffensive Rebound Season Average	Pearson Correlation	.093	-.413	**-.705****	.227
	Sig. (2-tailed)	.712	.088	.001	.366
	N	18	18	18	18
Assists Season Average	Pearson Correlation	.198	-.321	**-.598****	.234
	Sig. (2-tailed)	.431	.194	.009	.350
	N	18	18	18	18
Steals Season Average	Pearson Correlation	.444	-.128	-.334	.339
	Sig. (2-tailed)	.065	.612	.176	.169
	N	18	18	18	18
Blocked Shots Season Average	Pearson Correlation	-.244	-.080	-.129	.086
	Sig. (2-tailed)	.329	.753	.611	.733
	N	18	18	18	18
Total Points Season Average	Pearson Correlation	.178	-.136	-.429	.384
	Sig. (2-tailed)	.480	.590	.075	.115
	N	18	18	18	18

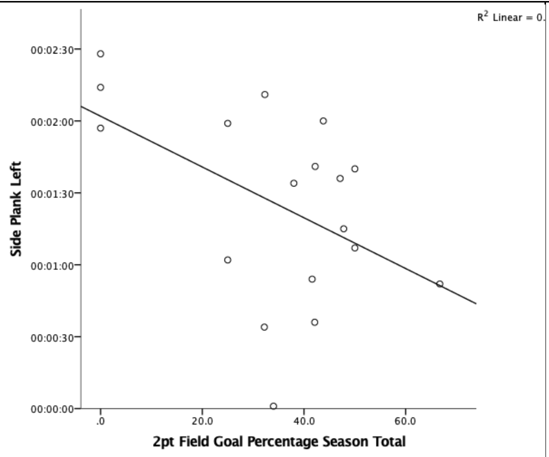
In this table *. Correlation is significant at the 0.05 level (2-tailed) and **. Correlation is significant at the 0.01 level (2-tailed).

Table 4.22 Core Strength Endurance and Stability Correlations with Injuries.

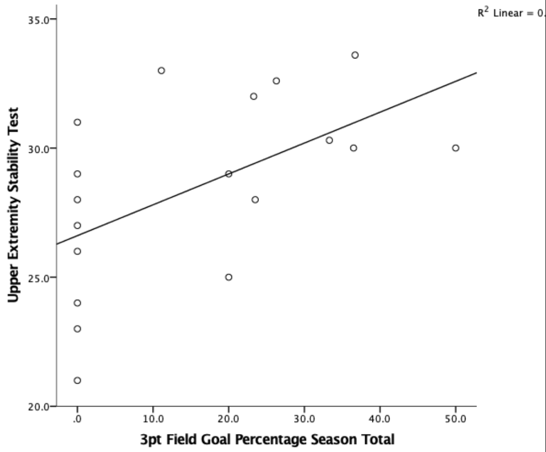
		Sport Specific Plank	Side Plank Right	Side Plank Left	Upper Extremity Stability Test
Did athlete sustain injury	Pearson Correlation	.144	-.150	-.096	.084
	Sig. (2-tailed)	.569	.553	.705	.740
	N	18	18	18	18
Time Loss Injuries	Pearson Correlation	.069	-.095	-.188	-.014
	Sig. (2-tailed)	.785	.709	.454	.956
	N	18	18	18	18
Non-Time Loss Injuries	Pearson Correlation	.036	.102	-.071	.231
	Sig. (2-tailed)	.886	.688	.780	.357
	N	18	18	18	18
Total Number of Injuries	Pearson Correlation	.077	-.026	-.196	.109
	Sig. (2-tailed)	.760	.918	.436	.667
	N	18	18	18	18

In this table *. Correlation is significant at the 0.05 level (2-tailed) and **. Correlation is significant at the 0.01 level (2-tailed).

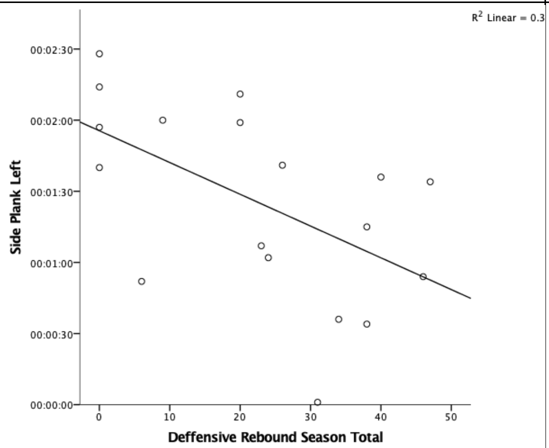
Table 4.23 Selected Core Strength Endurance and Stability Tests and Performance Outcome Associations Scatter Plots.



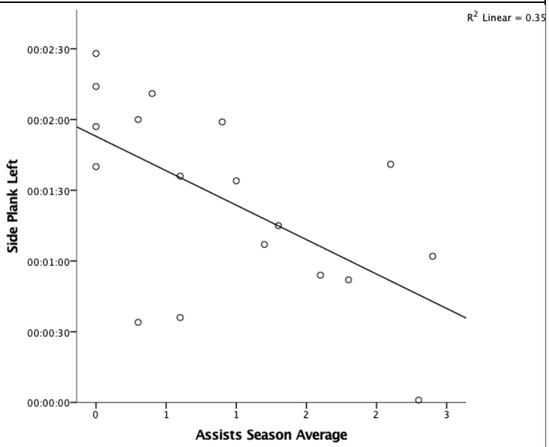
This scatter plot shows a moderate, negative, linear association between side plank left and number of games played season total.



This scatter plot shows a moderate, positive, linear association between upper extremity stability test and 3pt field goal percentage season total.



This scatter plot shows a moderate to strong, negative, linear association between side plank left and defensive rebound season total.



This scatter plot shows a moderate to strong, negative, linear association between side plank left and assists season average.

(5) Agility and Speed

Correlations for agility, speed and aerobic tests group on performance outcomes using Pearson product-moment correlation (Table 4:21) showed a strong negative correlation between 5M sprint and assists season average (r = -0.72, n = 18, p < 0.01). Agility T-Test had strong negative correlation with number of games played season average (r = -0.62, n = 18, p < 0.01), defensive rebound season average (r = -0.64, n = 18, p < 0.01) and total points season average (r = -0.66, n = 18, p < 0.01). Agility T-Test showed moderate negative correlation with 2pt field goal season percentage (r = -0.56, n = 18, p < 0.05). No significant correlations were found between the agility, speed and aerobic test group and injuries (Table 4:22).

Table 4.24 Agility, Speed and Aerobic Correlations with Game Performance Outcomes.

		5M Sprint	10M Sprint	20M Sprint	Reactive Agility Test	Non-Reactive Agility Test	Agility T-Test	Yo Yo Intermittent Level 1 Test (M)
Number of Games Played Season Average	Pearson Correlation	-.445	-.333	-.332	-.093	-.034	**-.625****	.419
	Sig. (2-tailed)	.064	.176	.178	.721	.898	.006	.074
	N	18	18	18	17	17	18	19
2pt Field Goal Percentage Season Average	Pearson Correlation	-.263	-.134	-.234	.174	.093	**-.569***	-.004
	Sig. (2-tailed)	.292	.597	.351	.504	.721	.014	.987
	N	18	18	18	17	17	18	19
3pt Field Goal Percentage Season Average	Pearson Correlation	-.119	-.214	-.106	.064	.284	-.434	.274
	Sig. (2-tailed)	.638	.394	.676	.807	.269	.072	.256
	N	18	18	18	17	17	18	19
Free Throws Made Season Average	Pearson Correlation	-.322	-.334	-.040	.170	-.091	-.391	.103
	Sig. (2-tailed)	.192	.176	.876	.514	.727	.109	.675
	N	18	18	18	17	17	18	19
Free throw Percentage Season Average	Pearson Correlation	-.205	-.279	-.190	-.012	-.210	-.412	.386
	Sig. (2-tailed)	.415	.262	.451	.962	.418	.090	.102
	N	18	18	18	17	17	18	19
Offensive Rebounds Season Average	Pearson Correlation	-.084	.116	.066	.190	.064	-.288	-.197
	Sig. (2-tailed)	.740	.646	.796	.464	.808	.246	.418
	N	18	18	18	17	17	18	19
Deffensive Rebound Season Average	Pearson Correlation	-.229	-.041	-.231	-.056	.227	**-.645****	.310
	Sig. (2-tailed)	.361	.871	.357	.832	.381	.004	.197
	N	18	18	18	17	17	18	19
Assists Season Average	Pearson Correlation	**-.727****	-.400	-.276	-.178	-.028	-.442	.453
	Sig. (2-tailed)	.001	.100	.267	.495	.914	.066	.052
	N	18	18	18	17	17	18	19
Steals Season Average	Pearson Correlation	-.376	-.336	-.223	-.013	-.052	-.380	.455
	Sig. (2-tailed)	.125	.172	.374	.960	.844	.119	.050
	N	18	18	18	17	17	18	19
Blocked Shots Season Average	Pearson Correlation	.163	.076	.236	.435	.400	.003	-.221
	Sig. (2-tailed)	.517	.763	.346	.081	.112	.991	.363
	N	18	18	18	17	17	18	19
Total Points Season Average	Pearson Correlation	-.420	-.251	-.107	.185	.010	**-.667****	.222
	Sig. (2-tailed)	.083	.316	.672	.477	.970	.003	.362
	N	18	18	18	17	17	18	19

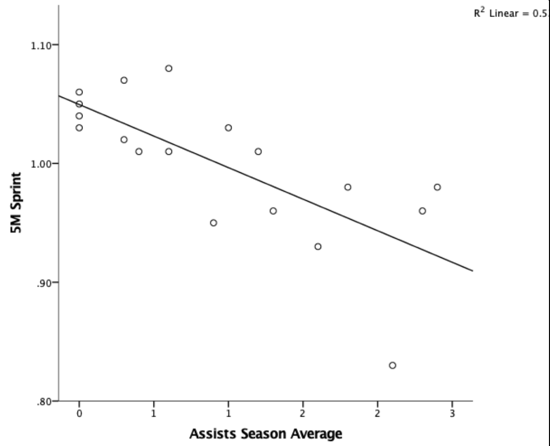
In this table *. Correlation is significant at the 0.05 level (2-tailed) and **. Correlation is significant at the 0.01 level (2-tailed).

Table 4.25 Agility, Speed and Aerobic Correlations with Injuries.

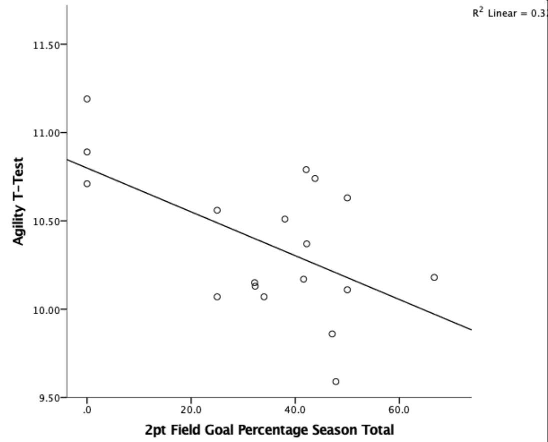
		5M Sprint	10M Sprint	20M Sprint	Reactive Agility Test	Non-Reactive Agility Test	Agility T-Test	Yo Yo Intermittent Level 1 Test (M)
Did athlete sustain injury	Pearson Correlation	-.181	.136	.051	-.080	-.193	-.322	-.041
	Sig. (2-tailed)	.472	.590	.842	.761	.458	.193	.869
	N	18	18	18	17	17	18	19
Time Loss Injuries	Pearson Correlation	-.137	-.276	-.215	.008	-.363	-.207	.015
	Sig. (2-tailed)	.587	.267	.392	.976	.152	.409	.952
	N	18	18	18	17	17	18	19
Non-Time Loss Injuries	Pearson Correlation	-.204	-.115	.062	.122	.252	.045	.220
	Sig. (2-tailed)	.417	.648	.808	.641	.329	.860	.366
	N	18	18	18	17	17	18	19
Total Number of Injuries	Pearson Correlation	-.222	-.293	-.148	.063	-.207	-.151	.126
	Sig. (2-tailed)	.375	.237	.557	.809	.425	.549	.607
	N	18	18	18	17	17	18	19

In this table *. Correlation is significant at the 0.05 level (2-tailed) and **. Correlation is significant at the 0.01 level (2-tailed).

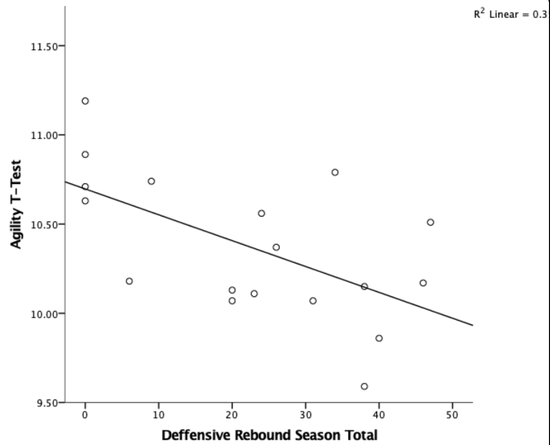
Table 4.26 Selected Agility, Speed and Endurance Tests and Performance Outcome Associations Scatter Plots.



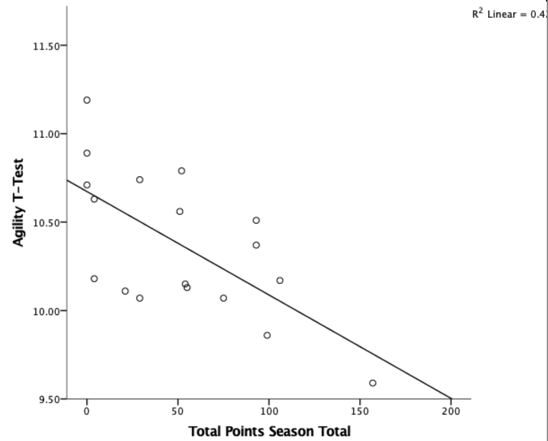
This scatter plot shows a moderate, negative, linear association between 5M sprint and assists season average.



This scatter plot shows a moderate, negative, linear association between agility T-test and 2pt field goal percentage season total.



This scatter plot shows a moderate, negative, linear association between agility T-test and defensive rebound season total.



This scatter plot shows a moderate, negative, linear association between agility T-test and total points season total.

(6) Jump Tests and Reactive Strength Index

No significant correlations were found between jump tests and reactive strength index and game performance outcomes or injuries.

Table 4.27 Jump Tests Correlations with Game Performance Outcomes.

		Double 4 Vert Jump Height cm	Double 4 Vertical Jump CGT (secs)	Reactive Strenght Index 4 Jump Do	Counter Movement Jump Board	Counter Movement Jump Board Right	Counter Movement Jump Board Left
Number of Games Played Season Average	Pearson Correlation	.383	.005	.114	.105	.143	.034
	Sig. (2-tailed)	.105	.982	.642	.699	.599	.900
	N	19	19	19	16	16	16
2pt Field Goal Percentage Season Average	Pearson Correlation	.197	.016	.050	.057	-.034	.014
	Sig. (2-tailed)	.418	.947	.838	.834	.900	.960
	N	19	19	19	16	16	16
3pt Field Goal Percentage Season Average	Pearson Correlation	.320	.073	.050	-.050	.095	.009
	Sig. (2-tailed)	.182	.766	.838	.855	.727	.972
	N	19	19	19	16	16	16
Free Throws Made Season Average	Pearson Correlation	.186	.069	-.061	.208	.144	.054
	Sig. (2-tailed)	.446	.780	.805	.440	.594	.842
	N	19	19	19	16	16	16
Free throw Percentage Season Average	Pearson Correlation	.262	-.306	.415	.135	.283	.194
	Sig. (2-tailed)	.279	.202	.077	.619	.288	.471
	N	19	19	19	16	16	16
Offensive Rebounds Season Average	Pearson Correlation	.088	.206	-.237	.193	-.084	-.044
	Sig. (2-tailed)	.719	.398	.328	.474	.757	.871
	N	19	19	19	16	16	16
Deffensive Rebound Season Average	Pearson Correlation	.284	.133	-.043	.138	.007	-.069
	Sig. (2-tailed)	.238	.587	.861	.610	.980	.798
	N	19	19	19	16	16	16
Assists Season Average	Pearson Correlation	.192	-.075	.093	.222	.277	.095
	Sig. (2-tailed)	.432	.762	.706	.409	.299	.725
	N	19	19	19	16	16	16
Steals Season Average	Pearson Correlation	.161	-.204	.314	-.032	.208	-.008
	Sig. (2-tailed)	.511	.402	.190	.906	.441	.978
	N	19	19	19	16	16	16
Blocked Shots Season Average	Pearson Correlation	-.123	.180	-.325	-.185	-.384	-.362
	Sig. (2-tailed)	.616	.460	.174	.494	.142	.169
	N	19	19	19	16	16	16
Total Points Season Average	Pearson Correlation	.341	.234	-.083	.129	.098	-.006
	Sig. (2-tailed)	.154	.334	.735	.635	.719	.983
	N	19	19	19	16	16	16

In this table *. Correlation is significant at the 0.05 level (2-tailed) and **. Correlation is significant at the 0.01 level (2-tailed).

Table 4.28 Jump Tests Correlations with Injuries.

		Double 4 Vert Jump Height cm	Double 4 Vertical Jump CGT (secs)	Reactive Strenght Index 4 Jump Do	Counter Movement Jump Board	Counter Movement Jump Board Right	Counter Movement Jump Board Left
Did athlete sustain injury	Pearson Correlation	.145	-.185	.160	.341	.026	.175
	Sig. (2-tailed)	.554	.448	.512	.196	.924	.517
	N	19	19	19	16	16	16
Time Loss Injuries	Pearson Correlation	.243	.218	.084	.004	.068	.017
	Sig. (2-tailed)	.317	.369	.733	.987	.801	.949
	N	19	19	19	16	16	16
Non-Time Loss Injuries	Pearson Correlation	-.123	-.200	.108	-.147	.319	.060
	Sig. (2-tailed)	.615	.411	.659	.587	.229	.825
	N	19	19	19	16	16	16
Total Number of Injuries	Pearson Correlation	.134	.074	.125	-.073	.223	.046
	Sig. (2-tailed)	.584	.762	.612	.788	.406	.866
	N	19	19	19	16	16	16

In this table *. Correlation is significant at the 0.05 level (2-tailed) and **. Correlation is significant at the 0.01 level (2-tailed).

Multiple Regression Analysis

The results for Model 1 multiple linear regression suggest that although the proportion of the total variation in 2pt Field Goal Percentage Season Total was predicted by the combination of active Range of Movement (ROM) parameters F (12,5) = .658, p < .005, no individual predictor emerged as significant. Additionally, we found that R^2 indicates that approximately 61% of the variation in 2pt Field Goal Percentage Season Total was predicted by Active ROM parameters set out in Table 4.29.

Table 4.29 Multiple Regression Model 1: Active ROM (IV) and 2 pt Field Goal Percentage (DV)

Model 1	R	R^2	Adjusted R^2	F	Sig.
	.782[a]	.612	-.319	.658	.745[b]
	Unstandardized Coefficients B	**Std. Error**	**Standardized Coefficients Beta (β)**	**t**	**Sig.**
(Constant)	150.531	76.957		1.956	.108
Left Shoulder Active Int Rot	-.754	1.020	-.701	-.739	.493
Right Shoulder Active Int Rot	.296	1.039	.277	.285	.787
Left Shoulder Active Ext Rot	-.477	.828	-.320	-.576	.589
Right Shoulder Active Ext Rot	.138	.800	.093	.173	.870
Left Hip Active Int Rot	-1.545	1.020	-.880	-1.515	.190
Right Hip Active Int Rot	.763	1.525	.490	.500	.638
Left Hip Active Ext Rot	-1.039	1.388	-.358	-.748	.488
Right Hip Active Ext Rot	.508	1.122	.266	.452	.670
Left Plantar Flex Active	-.426	1.013	-.244	-.420	.692
Right Plantar Flex Active	.664	1.914	.311	.347	.743
Left Dorsiflexion Active	-.699	4.433	-.141	-.158	.881
Right Dorsiflexion Active	1.465	2.905	.273	.504	.635

a. Dependent Variable: 2pt Field Goal Percentage Season Total
b. Predictors: (Constant), Right Dorsiflexion Active, Right Shoulder Active Ext Rot, Left Shoulder Active Int Rot, Left Hip Active Ext Rot, Right Hip Active Int Rot, Left Plantar Flex Active, Right Hip Active Ext Rot, Left Shoulder Active Ext Rot, Left Hip Active Int Rot, Right Plantar Flex Active, Left Dorsiflexion Active, Right Shoulder Active Int Rot.

The results for Model 2 multiple linear regression suggest that a significant proportion of the total variation in Free Throw Percentage Season Total was predicted by Left Hamstring 90/90 Independent variable F (6,12) = 3.163, $p <$ .005. Additionally, we found that R^2 indicates that approximately 61% of the variation in Free Throw Percentage Season Total was predicted by lower limb parameters set out in Table 4.30.

Table 4.30 Multiple Regression Model 2: Lower Limb ROM (IV) and Free Throw Percentage (DV)

Model 2	**R**	**R^2**	**Adjusted R^2**	**F**	**Sig.**
	.783[a]	.613	.419	3.163	.042[b]
	Unstandardized Coefficients		**Standardized Coefficients**		
	B	**Std. Error**	**Beta (β)**	**t**	**Sig.**
(Constant)	-148.666	168.053		-.885	.394
Right Straight Leg Raise	2.492	1.993	.678	1.251	.235
Left Straight Leg Raise	-.582	2.580	-.111	-.225	.825
Right Hamstring 90/90	-1.604	1.254	-.452	-1.280	.225
Left Hamstring 90/90	2.948	1.317	.566	2.239	**.045**
Left Dorsiflexion Passive	.049	.173	.058	.283	.782
Right Dorsiflexion Passive	-.791	1.910	-.102	-.414	.686

a. Dependent Variable: Free throw Percentage Season Total

b. Predictors: (Constant), Right Dorsiflexion Passive, Left Dorsiflexion Passive, Left Hamstring 90/90, Left Straight Leg Raise, Right Hamstring 90/90, Right Straight Leg Raise

The results for Model 3 multiple linear regression suggest that a significant proportion of the total variation in Assists Season Average was predicted by 5M Sprint Independent variable *F* (6,10) = 6.375, *p* < .005. Additionally, we found that R^2 indicates that approximately 79% of the variation in Assists Season Average was predicted by lower limb and agility parameters set out in Table 4.31.

Table 4.31 Multiple Regression Model 3: Ankle ROM, Agility and Sprint (IV) and Assists Season Average (DV)

Model 3	**R**	**R^2**	**Adjusted R^2**	**F**	**Sig.**
	.890[a]	.793	.668	6.375	**.006[b]**
	Unstandardized Coefficients		**Standardized Coefficients**		
	B	**Std. Error**	**Beta (β)**	**t**	**Sig.**
(Constant)	12.207	3.353		3.641	**.005**
Left Dorsiflexion Passive	-.001	.003	-.046	-.288	.779
Right Dorsiflexion Passive	-.051	.040	-.281	-1.249	.240
Agility T-Test	-.076	.443	-.041	-.170	.868
Reactive Agility Test	-.060	.053	-.219	-1.130	.285
Non-Reactive Agility Test	.048	.022	.366	2.116	.060
5M Sprint	-9.445	2.165	-.767	-4.363	**.001**

a. Dependent Variable: Assists Season Average
b. Predictors: (Constant), 5M Sprint, Left Dorsiflexion Passive, Reactive Agility Test, Right Dorsiflexion Passive, Non-Reactive Agility Test, Agility T-Test

The results for Model 4 multiple linear regression suggest that although lower limb and agility parameters together predicted total variation in Steals Season Average *F* (6,10) = 1.118, *p* < .005, no individual predictor emerged as significant. Additionally, we found that R^2 indicates that approximately 40% of the variation in Steals Season Average was predicted by lower limb and agility parameters set out in Table 4.32.

Table 4.32 Multiple Regression Model 4: Ankle ROM, Agility and Sprint (IV) and Steals Season Average (DV)

Model 4	**R**	**R^2**	**Adjusted R^2**	**F**	**Sig.**
	.634[a]	.401	.042	1.118	.417[b]

	Unstandardized Coefficients		**Standardized Coefficients**		
	B	**Std. Error**	**Beta (β)**	**t**	**Sig.**
(Constant)	8.215	3.930		2.091	.063
Left Dorsiflexion Passive	-.003	.003	-.216	-.787	.449
Right Dorsiflexion Passive	.006	.047	.046	.121	.906
Agility T-Test	-.731	.520	-.577	-1.407	.190
Reactive Agility Test	.037	.063	.197	.598	.563
Non-Reactive Agility Test	.002	.026	.022	.074	.942
5M Sprint	-1.544	2.537	-.182	-.609	.556

a. Dependent Variable: Steals Season Average
b. Predictors: (Constant), 5M Sprint, Left Dorsiflexion Passive, Reactive Agility Test, Right Dorsiflexion Passive, Non-Reactive Agility Test, Agility T-Test

Chapter 5

Discussion

This project was conducted to provide valuable insight into how and why I administer screening tests and if these can be improved, changed or withdrawn altogether. Secondly, the relationship screening tests have with on-court performance is becoming increasingly important with many coaches focusing on more functional and sport-specific training. The importance of interpreting the results and how we apply that interpretation to practice is key to utilising these new findings. My findings will be discussed in the groups they are detailed in the results section. Implications for practice will be allied to each group discussion but the overarching implications for practice will supersede the discussion section.

(1) Baseline Clinical Tests

Baseline and ROM Upper Limb Correlations with Game Performance Outcomes.

Anthropometrics of players affect performance across many sports with some individual's talent spotted because of their height, size, and length of levers (Johnston et al., 2017). Basketball is no exception to this, with height being a key measure that has the potential to influence game outcomes (Hoare, 2010, Torres-Unda et al., 2013). The positive correlation in this study of height and both blocked shots and offensive rebounds are of no surprise, but I need to further understand why there was no correlation with defensive rebounds. Essentially these are similar actions at either end of the court although admittedly perceptive requirements would be different when I compare a defensive versus offensive players position and aims on court. It could be that players are stimulated to a greater degree by offensive play than defensive play. If offensive play is a stimulus to better outcomes for those players with height, coaches will want to find a way to transfer this to defensive rebounds. It is likely the correlation or lack of it will not be of a surprise to coaches, but the evidence will reinforce their belief that players will work harder on offense.

This belief is clear in conversations and through observations of what coaches' demand and what they must reinforce as their style of play. Coaches also explain the difference in on court position for rebounding. Offensive is momentum based as players move toward the basket and defensive is more static and under the basket. This changes the requirements and movements physically that may impact on correlations. Understanding the key differences will provide improved planning in the screening, conditioning, and rehabilitation of basketball players. Moreover, Hoffman et al. (1996) found that coach's evaluation of a player was the most influential factor in playing time by between 6-20%, despite physical and physiological characteristics.

Anthropometric measures and performance testing have been researched previously (Hoare, 2010) but no research to date has looked at anthropometrics and game performance outcomes. Comparisons are therefore difficult to make but Hoare (2010) does convey the fact basketball is shaped by position and how a player's body type is suited to it. This in my experience also relates to game performance outcomes as there are some elements in a game that your position and physical attribute will lean you toward. Indeed, players are aware of statistics and chase them in competitions to be top of, for instance points scored or total rebounds. This is even more prominent at high level European competitions I have been part of, and all players know what they are likely to achieve in regard to statistics. Hoare (2010) does go on to state that the best players are distinguished form the rest by factors including anthropometrics like height, and physiology.

A correlation between blocked shots and height is a predictable outcome, as is the correlation with player position (Peunte et al., 2017). Roles and/or playing position influence game statistics although, game statistic should be interpreted carefully as the percentage made is dependent on the number of attempts. Higher percentages are tempered by the opportunity of exposure to achieve a game statistic (Sampaio et al. 2015). Studies suggest playing position is influenced by physiological demands and body type (Abdelkrim et al. 2007; Köklü et al. 2011; Sampaio et al. 2006). It is challenging to separate individual characteristics from playing position as they are interlinked and dependant on level and make up of a team some positions between players may be more interchangeable. Blocked shots can be from the speed of movement from more agile players like guards or from centres having the height advantage that enables them to block or intervene the path of the ball. Each player will utilise his physical advantage to gain the upper hand. A key element is ensuring coaches and wider support staffs understand a player's physical advantage. Without this clear definition the advantages are less likely to be maximized. It is my observation from basketball at all levels that players beliefs of what their strengths are often differ from that of the coach’s view. This is more openly evident at national teams where players are to fit within a team of talented players but may have been used to play a specific way at their club.

A key component in interpreting the results is understanding the narrative outlined earlier in the paper focusing on a more functional and, sport specific synergy between what we test for and the movements used throughout training and games in basketball. Many of the tests will not have been applied specific to a sport so whilst we have predictable outcomes like height and rebounds others have no precedence. This is particularly true when considering shoulder range of motion and game performance outcomes.

Differences between active and passive internal rotation of the shoulder on 2- and 3-point Field Goals may suggest an anomaly, as passive has negative correlation and active is positive. The biomechanical model of shooting may be considered here, as a greater degree of passive movement of shoulder internal rotation would bring the arm toward the midline of the body. Okazaki et al. (2015) review details the five phases of shooting and the position of the shoulder joint. Preparation phase has shoulder rotation on release with the following elevation phase seeing a range of motion from the shoulder in flexion from 90° – 135°. The stability phase recognizes angular displacement with the superseding release phase leading to an upper limb multi joint simultaneous movement. The final phase of follow through holds the shoulder in a flexed position. However, active shoulder range of movement had negative correlation with 2pt Field Goals that could suggest the lesser the range of active internal movement of the shoulder the better the biomechanical and technical alignment that has positive effects on field goal percentages. Active internal range of motion and biomechanical and technical alignment have yet to be considered in research and would need to confirm a technically agreed model, shoulder range of motion and game statistics using video playback. Whilst my theory of biomechanical alignment supports the results in a logical way it would need to be tested.

To reinforce the theory of biomechanical alignment both passive and active shoulder external rotation bilaterally had strong positive correlations with offensive rebounds. This suggests a greater degree of external rotation allows for increased functional and sport specific range of motion therefore providing a path of less resistance to having the arms overhead without the need for compensations. Research shows that shoulder external rotation is a key component of overhead activities if optimal performance is to be realized. This is sometimes offset by a reduction in internal rotation when comparisons are made between a throwing arm and non-throwing arm (Herrington, 1998). The need to understand ROM in joints and how this is developed is important. Borsa et al., (2008) suggests acquired adaptation gain for shoulder external rotation termed External Rotation Gain (ERG) was 5°-12° from athletes with repeated movements. This was seemingly traded by Glenohumeral Internal Rotation Deficit (GRID) of between 8°-15°. Most of the studies in this area are form sports with far more repeated overhead action and more unilateral work. Limited evidence exists in basketball where a significant percentage of the overhead work is bilateral. In a recent systematic review with meta-analysis no significance was found for shoulder ROM measures but did suggest, in line with previous studies, that GRID related to injury as did total shoulder rotational loss and external rotation gain (Keller et al. 2018).

When considering upper limb range of motion and baseline measures, and how they may relate to game performance, the implications for practice change very little. Some measures like height will have a direct impact on games based on physical attributes, but also shoulder range of motion in general do tie in to limited game statistics based around biomechanics and alignment. However, even though correlations are only found with a few game statistics, as a clinician who will screen athletes' pre-season, I still require a baseline measure of range of motion from which I can compare should an athlete sustain an injury.

The question on future practice now is really whether I include all shoulder measures as a baseline or refine them between active and passive. The fact I see correlations specific to active or passive as well as both to specific game outcomes would suggest we measure both. This is a change from previously where predominantly passive would be used for shoulder internal and external rotation.

I will consider in practice how I develop player's ability to utilise height during rebounding specific to offense or defense. I can work on this during training sessions with coaches by improving players anticipation and training players ability to rebound with and without momentum akin to different segments of play. Incorporating drills into part of our conditioning programme allied to vertical jump work will help maximize the height players have. From experience, taller players I have worked with tend to work less on vertical jump height as they feel it is not needed. From a performance perspective maximizing all elements of physical capability provides improved outcomes so long as the reaction, anticipation and perceptual components are equally up to speed.

Range of Motion Lower Limb Correlations with Game Performance Outcomes

Interpreting results from lower limb range of motion testing and performance outcomes appears to lead us to a similar position as the upper limb. A pattern of optimal alignment with the great toe over the knee as in Qualitative Assessment of Single Leg Squat (Hewett et al., 1999; Earl., 2005; Wilson et al.,2006) ties into the negative correlation between hip internal rotation, both passive and active, and free throws and 2pt field goals. As I see greater internal rotation of the hip, regardless of whether it is active or passive, the knee will track toward or across the midline of the body suggesting a reduction in optimal biomechanics negatively affecting both free throws and field goals.

The biomechanical alignment belief is further enhanced by hip external rotation positively correlating with free throws, meaning alignment of the knee and great toe are more optimal not across the midline. Although from a practical perspective is logical, given the importance of alignment in activity and sport and fundamental movement like squatting (Schoenfeld, 2010), what is more important is that measuring passively or actively does not provide further information from baseline to performance. A consideration throughout my project that has become more prominent is what the results tell me in terms of what is necessary. Time is a precious commodity, so refinement of screening and testing measures need clarity on what is influenced by those tests with regard to performance.

Hip rotation is difficult to compare with other studies as different methods have been used. The only study looking at screening tests and performance outcomes in basketball used a prone position that is considered a less functional position. This may be why no correlation was found in the McGill et al. (2012) study in comparison to ours. It should however be recognised the McGill et al (2012) study was over a longer period but with fewer participants.

Hamstring flexibility is a fundamental measure used in many baseline screening test protocols (Dallinga et al., 2012) with the results from this study reinforcing how heavily correlated it is with performance outcomes. However, I do need to differentiate between Straight Leg Raise and Hamstring 90/90. The former does indeed include partial hamstring flexibility but is also a neural test and uses gluteal and lumbar spine for some movement (Fritz, 2012). The latter is what we as clinicians refer to as pure hamstring length.

Consistent results for Straight Leg Raise left and right for free throws made, and percentages and steals suggest some significance especially as the difference between left and right was insignificant at 5°**.** The consistency of Straight Leg Raise validates the use of Straight Leg Raise in screening in basketball as a clear relationship to performance outcomes are seen in a clear pattern. McGill et al. (2012) had similar findings showing correlations with blocks per game, although the measure is more toward hip flexion range of motion as oppose to hamstring length.

Only one asymmetrical correlation between Left Straight Leg Raise and 3pt Field Goal was found. This could be an anomaly or may be influenced by the technical and mechanical components of shooting for a 3pt Field Goal (Rodacki et al., 2002; Okazaki et al., 2015). Without video playback of each 3pt Field Goal made an analysis of the 3pt Field Goal it is beyond the normal limits of my work and more for technical analysis by coaches.

The results provided me with a clear bias toward Right over Left Hamstring 90/90 test. Right Hamstring 90/90 had seven negative correlations and Left only one. This in effect means the lower a degree measure is equivalent to a greater Range of Motion. The range of correlations from free throws and field goals to assists and steals, suggests there is more than one element at play, as these movements require different activation patterns for each movement. As there is less than 1° difference between Left and Right Hamstring 90/90 it cannot be due to an asymmetry within the group. I hypothesize there is a varied and specific demand from left and right hamstring muscle group that impact on the outcomes of the task, be that static shooting or change of direction (COD). Similar to the Straight Leg Raise, to reach a definitive conclusion on this further investigation and analysis of key movements inclusive of free throws, steals, assists and field goals would need to be undertaken alongside testing, with the possible inclusion of EMG. Interestingly, McGill et al. (2012) study also showed a favouring to the right side at a ratio of 2:1. A key area we have not factored in here is dominant side.

This could have a bearing on the correlations but fully understanding our game time and motion data alongside specific movement data inclusive of muscle activity using EMG and technical analysis may provide more information for which to draw conclusions.

A practical interpretation of my results is that I must be consciously aware when screening to link test results of hip range of motion to biomechanical alignment. What I see on internal rotation should lead to a degree of predictability on tests like Single Leg Squat. I acknowledge here that muscle strength is also a factor that was not tested in this protocol but is tested within our academy setting. During this testing I see clear and repeated correlations (from testing, not statistical analysis) between lower limb abductor weakness and sub-optimal biomechanical alignment, especially on single leg loaded tasks.

Furthermore, similar to the upper limb tests there appears to be no advantage for either passive or active testing, meaning either one can be used to make testing more efficient. Changes to screening practice have been implemented to make efficient time use and to acknowledge the type of test. Lower limb range of movement testing is now done passively only. This is more straightforward as both hamstring 90/90 and Straight Leg Raise should be passive tests.

One key element is how technical elements of the sport specific demands of basketball influence our testing and how they correlate to performance outcomes. Speaking with coaches they do not believe physiotherapists understand enough about the technical and biomechanical models relevant to basketball sport specific movements. A key change to my practice when hosting students is to get them to spend the first few sessions of placement shadowing coaches from different sports. This allows them to understand technical elements better and question coaches on what methods they employ to refine technique. The positive outcome is it has a wider impact on the student's rehabilitation strategies as they work toward more sport specific movement.

In conversation with coaches a greater ability to comprehend in game movements would better allow support staff to predict, check, correct and correlate specific movements be they isolated or complex multi-joint. Without this detailed knowledge, screening protocols will fall short of being able to reflect and relate to performance or injuries. The shortfall of game movement understanding has been highlighted repeatedly in Functional Movement Screen Tests and questioned by one review study, suggesting no correlation between hip range of motion and either pain or outcomes (Tak et al., 2017; Okada et al., 2011; Parchmann & McBride, 2011). Some debate can be had here as other research counters this with hip stability and active motion being potential components of pre-participation were found to correlate with pain and injury (Hegedus et al., 2016). Furthermore, the nature of multi-joint complex movements is understood in relation to a task from my experience as a physiotherapist. An example of this, reinforced by the shooting technical model detailed earlier in the paper (Okazaki et al. 2015) is the sequencing of joint movements relating to a jump shot. There must be adequate co-ordination, synergy and strength alongside technical ability to succeed at the task. Elements like optimal height and optimal release angle require specific physical characteristics to be present. This may not be maximal but must have enough for the technical skill.

Ankle Range of Motion Correlations with Game Performance Outcomes

Both predictable, and surprising in equal measure, were the results of ankle dorsiflexion. It is well evidenced that ankle dorsiflexion range of motion affects both performance and injury so it was anticipated some correlation would be found (Backman & Danielson, 2011; Malliaras et al., 2006). What was unexpected was that the correlation was negative, meaning the less range of motion there was the greater the correlation was found, with no fewer than seven game performance statistics. Correlation was greater on the right for passive dorsiflexion with no correlations found for active ankle range of motion for dorsiflexion or plantarflexion.

Interpretation of this is puzzling, aside from the expectation of correlations that deficits would relate to increased injuries. A common belief is ankle dorsiflexion provides a stable base from which to lock the ankle in place and produces a platform for greater ground reaction forces. Fung et al. (2011) considered the impact of ankle dorsiflexion on landing mechanics and found greater dorsiflexion range of motion produced a reduction in associated ground reaction forces. The way in which players land will inevitably have an impact on how they take off. Findings from Kovacs et al. (1999) found individuals landing heel first had less dorsiflexion than those landing mid to forefoot first. If I consider game and basketball specific movements it may provide an explanation as to why game performance outcomes, injury and ankle range of motion correlations, differ within the literature. Gonzalo-Skok et al., (2015) suggests we should consider asymmetries and functional movement as they contribute to understanding performance limitations. Although the functional tests showed no bearing on performance outcomes, when asymmetries between same joints on contralateral limbs were considered a relationship between asymmetry and COD was found for Weight bearing Dorsiflexion Lunge test. Okazaki and Rodacki (2012) found no difference between ankle and lower limb kinematics for 3 different shooting distances (2.8m, 4.6m and 6.4m). However, Cabarkapa, Fry and Deane (2021) found a difference in angle dorsiflexion angle movement from 2pt to 3pt shooting tasks. From phase 1 (crouch position) to phase 2 (tall release position) ankle dorsiflexion was found to increase relative to heel lift. This is thought to be for increased GRF to compensate for the increase in distance of shooting. A key area, particular in adolescent age athlete is co-ordination and sequencing of movement. Podmenik et al., (2017) found differences in joint angular movement from left to right. The study found that athletes with less experience had longer sequencing time. The link between technical movements and what is required at multiple joints is an area to consider how we improve sequencing and co-ordination in practice beyond the usual repetition approach.

During game play movements occur approximately every two seconds (Puente et al., 2016; Torres-Ronda et al., 2016; McInnes et al., 1995; Ben Abdelkrim et al., 2007). Movement can be any type, for instance jumping, landing, and jumping would be two movements. The movement of repeated jump landing is required for rebounding and may contribute to the discussion on why ankle dorsiflexion is less important in performance than it is for injuries. If ankle dorsiflexion is maximized during repeated jump movements the movement itself is longer in duration, most likely resulting in poorer outcomes as the opposition can react quicker. The duration of ground contact time must be evaluated whilst considering the research that looks at the Bosco Test (repeated jumps for 60 secs) and dorsiflexion. McNeil et al. (2010) found, unsurprisingly, that dorsiflexion reduced with increasing fatigue as did peak force over time.

Research has shown that restricted dorsiflexion changes landing mechanics and increases ground reaction forces (Fong et al., 2011; Whiting et al., 2011). Furthermore, the preparation of a consecutive jump also alters ankle dorsiflexion by reducing the range of movement on landing (Dill et al., 2014) and the shorter contact required for consecutive jumps increases lower leg stiffness when compared to stop landing mechanics (Arampatzis et al., 2001). In a recent review Mackay, Whatman and Reid (2017) found lower extremity stiffness changes to compensate for ankle dorsiflexion. The review does reflect that none of the papers looked at sport specific movement which is one of the main reasons why my findings may not be reflective of dorsiflexion expectation in basketball or sport in general. Sport specificity has played a role in my finding's, understanding these changes, and having an economical way to measure them is a greater challenge. Athletes will adapt and learn how to optimise attributes specific to a task. One example of this is that leg stiffness has an association with an increase in jump height and velocity and economy (Butler, Crowel III & Davis 2003).

The complex picture of whether dorsiflexion is desirable or not does seem to lead me to a more sport specific pathway. Detailed discussions with national team GB coaches' have highlighted the key differences between offensive and defensive rebounding. This has highlighted a movement difference not seen in testing. Offensive rebounding has more horizontal movement due to the momentum toward the opponent's basket, whereas defensive is more vertical and repeated under your own team's basket. Athletes with greater range of dorsiflexion jump higher compared to those with less dorsiflexion who have greater horizontal movement on jumping (Papaiakovou, 2013). Papaiakovou (2013) study may go some way explaining my findings of how ankle dorsiflexion relates to performance outcomes.

One way to evaluate this is to analyse repeated jumps using video with the cohort I work with and see the difference between ankle dorsiflexion range of motion and the amount of movement used during specific tasks, like repeated jumps. Analysis of in play movement patterns, would allow me to monitor horizontal and vertical movement.

Implications for practice are essentially twofold. Firstly, to analyse in training and in game movements to better understand specific requirements and how these movements are influenced by ankle range of motion. Secondly, continue ankle range of motion screening with a focus on passive range of motion. Additionally, the integrated elements of height, range of motion at the ankle, and their impact on performance relating to sport specific movements, reinforces the need for a better understanding of the training and game actual movements of our players. I have integrated analysis of movement causing injury from coach's video but have yet to develop this for analysis of movement due to time constraints. This is the next stage of fully understanding how movements differ from tests to court for each individual player.

Baseline and ROM Upper Limb Correlations with injuries.

Injury correlations tie into the pattern of upper limb movement discussed in the upper limb and game performance outcomes section of this discussion. Internal and external rotation of shoulder has specific properties when related to function that are relevant to injury in specific movements, particularly overhead, and the importance of finding the balance between mobility and stability (Braun et al., 2009). Injury findings are interpreted with caution due to the low number of both injuries and participants, and that only the right shoulder was found to have correlation with no specific pattern across active or passive evident. It is therefore difficult to draw any conclusion without a greater data pool other than an analysis of injuries and understanding how they occur, and how movement deficiencies may contribute to them.

Range of Motion Lower Limb Correlations with injuries.

Two significant findings from the lower limb group and injuries are worthy of consideration, even though the same caveats apply to this group of low participant numbers. The strong negative correlation between Hamstring 90/90 and non-time loss injury indicates a deficit in pure hamstring flexibility increases injury risk. I can only hypothesize as to why this may be as hamstring injury usually results in time loss injury with stretch type injuries taking a greater time to return to activity than contraction power-based injury (Askling et al., 2006). One possible hypothesis may be the low levels of hamstring injuries that occur are minor strains. Without access to appropriate imaging, it is impossible to affirm diagnosis within the academy setting with the resources available.

During recent teaching to physiotherapy students, a thought occurred to me that using different frameworks of muscle injury could be compared and used to determine if diagnosis differ from one framework to another (Mueller-Wohlfhart., et al 2012; Pollock et al., 2014; Valle et al., 2017). However, most still require confirmatory imaging that is not possible in my professional environment but using the frameworks to improve clinical reasoning may elicit a greater understanding of the injuries of players. Using the framework alongside the video of injury occurrence and usual subjective information will contribute to better understand and thus more appropriate interventions.

Hip external rotation has already been identified as fundamental to correct movement mechanics in functional movement. This understanding is reinforced with the negative correlation between active hip external rotation and time loss injuries. Hip external rotation and injuries have been indicated in other studies over the course of a season (Leetun et al., 2004). Leetun et al. (2004 predominantly looked at strength and injury association but found through regression analysis hip external rotation strength was the only predictor of injuries from five strength and strength endurance measures. However, it must be recognised Leetun et al. (2004) study was targeted toward strength and not range of motion and its findings are consistent with literature on knee injuries, hip external strength and alignment and biomechanics (Power, 2010; Nadler et al., 2000).

Currently no study to date has considered hip range of motion and injuries in basketball utilising the same evidenced based measurement techniques in functional positions. McGill et al. (2012) utilized non-functional prone position, which also tends to block on the opposing leg when externally rotating. McGill et al. (2012) also had smaller numbers than our cohort so inferences made from that study should be interpreted with caution, as is the case with ours. Several studies have found some biomechanical correlations between ACL injury and internal rotation of the hip joint, but this is much less about range of motion and more about strength, as in Leetun et al. (2004) study (Krosshaug et al., 2007). The reasons are two-fold why it is not necessary to go along this path. Firstly, we did not measure hip strength and, secondly, we did not have any ACL injuries.

Ankle Range of Motion Correlations with injuries.

Most ankle injury range of movement risks are associated with a lack of ankle dorsiflexion (Backman & Danielson, 2011; Malliaras et al., 2006). My findings from this project reinforces that pattern with active plantar flexion left and right showing a correlation with injury. The narrative plays into my belief, experience and evidence that increased plantar flexion effectively unlocks the foot making it less stable (Willems et al., 2004). The plantarflexion and stability link positive correlation would suggest increased plantar flexion increases the risk of non-specified injury, this is reinforced by the negative correlation of active right plantar flexion and number of injuries. Beynnon et al. (2002) in a study of 118 collegiate athletes found no correlation with injuries and ankle range of motion for both plantarflexion and dorsiflexion. They did find correlation with eversion range of motion in females. Combining these two statistics and evidence-based knowledge of dorsiflexion and injuries, whilst considering the low participant numbers does reveal a tentative pattern. However, as with game performance outcomes and ankle range of movement, the exact mechanism of injury and video analysis would confirm our findings by determining the position and degree of the ankle joint. Further progress on this has the potential to either reinforce my experiences observed and treated clinically across many sports or, in the case of performance and on court movements be the opposite to what I expect to see as a clinician thinking primarily of injuries.

Range of Motion: Implications for Practice.

Implications for my practice are for me to monitor, record and include in data analysis, the mechanism of injury with joint position reinforced by video playback. My change to practice in this area is to have clarity on the joint position at the time of injury. I have data on mechanism of injury and some access to video playback, but these were not used in this study for injuries, as it was thought the number of injuries would have been insufficient to draw any conclusion due to a lack of statistical power. I need to gain an understanding of whether the injury was contact or non-contact and to consider how the injury movement relates to basketball specific movement deficiencies. I will also look to observe more video and real time court-based work over a longer period of time for analysis that would allow an increase in participant numbers as they generally rotate on a two-year cycle. Considering my findings, it would be prudent to discuss as a medical team the inclusion of objective strength measures. I do this manually at screening, but this was not included in this project as manual testing is not reliable. However, my consistent application of manual strength testing coupled with me being the only person who screens, assesses, and treats athletes at the academy, means it is a valuable tool when more accurate objective methods are not viable.

The discovery of differences between range of motion and injuries compared to range of motion and performance does lead me to consider and understand how a deficit for one may be a risk and, for another, may be an enhancement. How I interpret findings from baseline range of motion screening and cross-reference this with performance and injuries will be part of my team's discussions moving forward. By 'my team' I mean the whole academy basketball coaching team, as it will require input from coaches in training and games and strength and conditioning coaches. Once the data and information are gathered it can be deciphered and interventions developed to reduce risk of injury or enhance performance.

(2) Neuromuscular Tests

Neuromuscular and Balance Correlations with Game Performance Outcomes.

Qualitative Assessment Single Leg Squat (QASLS) were consistent with my experience and previous research has been found to correlate bilaterally with some game performance outcomes (Okada et al., 2011). These were free throws made and offensive rebounds. The clear link previously identified in the lower limb range of motion segment provides an indication of how neuromuscular control, alignment, and balance, combine to affect functional movements some of which are sport specific. Good performance QASLS is evidenced to show improved hip abduction (Crossley et al., 2011). This is important and reflective of a narrative within the discussion that the biomechanics and understanding of sport specific movements like cutting and changing direction are optimized by improved alignment of the lower kinetic chain measured by QASLS (Hewett et al., 1999; Earl et al.,, 2005; Wilson et al., 2006; Alenezi et al., 2014).

My understanding is incomplete as to why QASLS only correlated with two game performance outcomes. Free throws being the most static type of shooting requires control, balance, alignment, alongside the coordination of movement. Good QASLS will allow for optimal biomechanical alignment and less internal “crumpling” as L. Herrington (personal communication, May 18, 2018) explains at the Basketball England Sports Medicine Conference during informal discussions. The basketball free throw requires minimization of movement variability particularly in the elbow and wrist (Button et al., 2003). The lower limb and its stability and alignment consequently affect movement and alignment in the upper limb.

One aspect of screening tests that I need to consider is the constraint of the task and what it is supposed to measure and how the sport specific tasks, like the free throw, should be integrated into the development of screening test. The factors to consider here for how these findings change practice are complex. I would need to evaluate if the shooting position at the high point with elbow flexed for free throws could be done during a QASLS test, and whether it provides any further useful information. I would then also have to consider if this is taking the sport specific element too far and potentially detracting from the quality, reliability, and validity of the test. Any changes to testing methods would need to be validated and will be thought through as the academy discuss these findings. The development of new testing protocols within my academy environment must gain court time from the coaches. I would then seek to not only develop and validate the test but like tests in this project, asses what relationship the tests have to performance and/or injuries. Even for one test this is a time-consuming process, but also one that has the potential to involve coaches far more as test criteria will require technical input and evaluation.

Within my academy setting QASLS provides more than game statistic and range of motion correlations. It also has a link to gluteus medius strength testing that is fundamental in assisting control of internal rotation and adduction of the hip although, strength associations with single leg squat appear not to cross over to more functional skills like running in previous studies (Crossley et al., 2011; Willy & Davis, 2011). Brughelli et al. (2008) found that strength training alone does not improve change of direction performance but single leg vertical, horizontal and sport specific training does. The functional strength relationship of QASLS and Brughelli et al. (2008) findings may indicate why QASLS correlated with offensive rebounds. As previously identified QASLS does challenge these elements at a basic level necessary to see how we can identify deficits as a baseline screening measure.

Y balance test and game performance outcomes seemed to elicit little clarity on how we interpret the negative correlations of posterior medial right and left with free throws. The pattern is consistent with both left and right tests correlating to the same outcomes, but the negative correlation is not as we expected or as literature that is supportive of Y Balance and Star Excursion Balance Tests (Olmsted et al., 2002; Gribble et al., 2012). My project suggests the lesser the reach and decreased mobility, the better outcomes for free throws. One possible explanation for this is the stance for free throws is a relatively narrow base on two feet that provides a stable base. Y balance is a single leg control and reach test that has little functional relevance to free throw technique based on studies that indicate release height of ball as a key determinant of success, alongside upper limb kinematics of the elbow and wrist (Tran & Silverberg, 2008; Button et al., 2003). Y Balance does not relate to a strong and stable double stance of the free throw that may go some way to explain my findings.

All other studies relating to either SEBT or Y Balance have a focus on injury correlation rather than sport performance outcomes. Only McGill et al. (2012) has to date looked at performance outcomes in basketball but, did not include Y Balance as one the tests. This data set in its unique form will require greater statistical power to understand if the Y Balance negative correlation in one direction has the meaning I hypothesize in relation to stance and stability. The implications and influence on my practice has been to look beyond what the statistics tell me. Y Balance like QASLS may not fit a particular pattern or be functional or sport specific, but elements of the test may mirror elements of the task. How I interpret data to understand not only what it tells me but also what it may not tell me directly, but indirectly, is a key step toward the development and use of tests for clear objective reasons.

Ankle Knee to Wall (AKTW) negative correlation with both defensive and offensive rebounds, offer the same explanations as the ankle range of motion testing. Although we know the ankle is locked in a dorsiflexed position thereby thought to produce better stability from which Ground Reaction Force (GRF) can be produced (Papaiakovou, 2013; Fung et al., 2011; McNeil et al., 2010), both offensive and defensive rebounds require quicker movement. If full dorsiflexion is achieved during rebounding this slows the action, negatively affecting the performance outcome for basketball specific movement. The less flexible ankle or decreased dorsiflexion has been shown to increase peak angular accelerations in all joints on repeated jumps (Papaiakovou et al., 2006). However, if I consider one single jump then dorsiflexion should be optimal as it lengthens the triceps surae enabling greater torque production (Faiss et al., 2010).

As with other outcomes a greater understanding of task specific requirements and demands coupled with biomechanics, kinetics, and alignment, are the progressions we take from neuromuscular control to our future screening and analysis. My project is making it clear that isolated or specific screening may only contribute to one component of a basketball skill. Neuromuscular control may be required for jump shots or change of direction tasks, but coordination, speed, strength and power are also additional physical variables needed, to name but a few. Further development of tests may only require a slight change like position of upper limb during a lower limb test, but these will have to be done in the same testing protocol to see the real value in an applied setting. Changes to my practice have been discussed with my academy team in the testing and screening that is in place for pre-season. This will no doubt require validation of tests with varying positions but will enable us over time to refine testing and be clearer on the importance of sport specificity that both I and coaches believe to be more relevant to game performance outcomes.

Neuromuscular and Balance Correlations with injuries.

Previous research has found correlations with neuromuscular tests and injuries (Gribble et al., 2012; Smith et al., 2015; Plisky et al., 2006; Hoch et al., 2011; Malliaras et al., 2006). My project found Y Balance Anterior reach with right leg correlating with ‘did athlete sustain injury’. No clear pattern emerges here, as this single correlation is not reinforced by other tests that have similar control elements coupled with range of motion. Other studies have found anterior reach asymmetry greater than 4cm or less than 94% of leg length for reach is at greater risk of injury. My study did not make asymmetrical comparisons within the correlation study but would be considered for future integration, although only the posterior medial reach direction was minimally greater than 4cm at 4.37cm.

QASLS identifies poor movement that may be a predictor of injury based on sub-optimal alignment but as in our study, research has not yet been found to have direct correlation with injuries. Neuromuscular control alongside strength is thought to be an important factor in injury prevention. Although this may be the case, identifying it through screening or testing proves difficult. In my applied setting I need to focus on the movements and demands of each of our players as individuals, not as an overall team or based on previous published time and motion studies. The change to practice requires more time to analyse digital data but is in my opinion one way in which I can work toward the detail I need to develop better performance outcomes and injuries within my academy. In national teamwork I am given a video of all injuries but, the limited time I have with players (2 weeks camp followed by 2 weeks European Championships) is insufficient time to implement individualised strategies that will have positive impacts on players.

(3) Comparative Upper Limb Physical Tests + CKCUEST

Upper Limb Physical Tests Correlations with Game Performance Outcomes.

Practical experience from many years of testing had made me question both the relevance and variability of some standard testing. Aligned to the Basketball England Advanced Apprenticeship in Sporting Excellence (AASE) and for national teams we had to use 3 kg med ball chest push. I have argued that 3kg is too light and provides a greater range of variability. The long sitting position is less functional and favors' technically competent throwers, reinforced by previous research (Clemons et al., 2010).

Applying the 45° angle seated bench 9kg med ball throw provided more consistent performance and less variability. Mean for 9kg med ball throw was 3.14 m +/- 0.33 SD. Correlation with number of games may be in part due to overall strength of an athlete and how they use strength during game play and testing. More notably, is the correlation with free throw percentages that may suggest a direct link to strength and the ability to deliver a free throw at the correct height. Given that research indicates one of the key variables alongside trajectory and speed of release is ball height, this is a plausible hypothesis (Tran & Silverberg, 2008). Hoffman et al., (1996) considered athlete performance and playing time in 29 make Division 1 collegiate players from the same team. The study found that when coach evaluation and playing experience was removed (accounting for 56%-86% and 6%-20% respectively of predicting playing time), performance tests accounted for 64%-81% of playing time. The most important factors were leg strength (squat 1RM), vertical jump, agility (T-Test), speed and upper limb strength (bench press 1RM). Vertical jump was found to be the strongest and most consistent factor associated with playing time. This study also suggests there is a minimum level of aerobic fitness required and that players with aerobic levels beyond the required provides not greater benefit compared to those with average levels. Furthemore, Delextrat & Cohen (2008) looked toward a standard evaluation of physical testing in basketball with both aerobic and anaerobic tests used. The study found that anaerobic power was the fundamental difference between elite and non-elite players, suggesting the importance of strength in relation to the level and abilities of players.

An important and immediate change to practice was the inclusion of the 9Kg med ball chest push. The test is more consistent and is better suited to the age and level of my academy athletes. One notable fact is in national teams all age groups would use the same weight ball for long sitting chest push. I have eradicated this blanket approach for my athletes taking into account age and gender.

The unilateral seated shot showed positive correlation with number of games played similar to the bilateral throw, and had additional positive correlations with blocked shots, and total points scored in a season. In my view the number of games is most likely related to strength in this age group. Blocked shots and total points can lead to several theories. It is possible that strength provides the player with a greater ability to produce force thereby enabling a player to move the upper limb grossly at speed to block opponents passing or shooting.

There is of course a perceptive element that we are not able to measure here, but the physical parameters and abilities of a player are a key part of this. The strength, speed, accuracy, stability, and sports specific perceptual abilities of a player will all contribute to the success at specific tasks. These reinforce my belief, with support from my data, that it is extremely difficult to separate specific testing from complex movements and tasks on court. The consistency of the unilateral seated shot putt has led me to implement this after comparison and discussion with the academy strength and conditioning coach. Unilateral testing does enable me to identify where asymmetries may be although I acknowledge it is not simple to understand if there is a lack of strength, or speed, or both. However, working in collaboration with strength and conditioning coaches we are able to narrow down athletes needs and address them systematically one by one, trying to home in on what the deficit is in relation to a test and on court performance.

Upper Limb Physical Tests Correlations with Injuries.

Within the season the data was recorded, there were no upper limb injuries, other than finger or thumb injuries. It is therefore unsurprising that no correlation with injuries were identified for upper limb performance tests. The consistency and improvement of the throws testing across the team, and by individuals, shows our strength and conditioning is addressing upper limb weakness over a planned season that is in turn having a positive effect on injury outcomes in the shoulder region. There is also the possibility that players do not report all injuries for fear of not being selected or ruled out by the medical team.

(4) Strength Endurance and Stability

Core Strength Endurance and Stability Correlations with Game Performance Outcomes.

Previous research has indicated a link between core stability and performance outcomes. McGill et al. (2012) found no correlation between core strength endurance tests and basketball game performance outcomes in an American university team across two seasons. McGill et al. (2012) did find that a lesser amount of segmental twist and segmental lateral bend of the trunk correlated with games and minutes played and rebounds per game indicating a stiffer torso was beneficial to performance.

My study showed only negative correlations between left side plank and 2pt field goals, defensive rebounds, and assists. The latter two were a strong and moderate correlation respectively and suggest less duration holding a side plank is related to better game performance outcomes. The left side plank correlations are unexpected so a theory as to why is discussed. Experience in testing core stability or core strength endurance and how a good performance on these tests appear to suggest better game performances. My thoughts from observation and screening have led me to relate core stability and strength endurance to game performance outcomes aligned to Kibler et al. (2006) "proximal stiffness enhances distal mobility". Whilst this is thought to be true in terms of performance and force generation, what our core stability and strength tests do not measure is tension. Core strength endurance tests purely look at the time an individual can hold a set position, with no understanding of how strong a contraction or tension or muscle stiffness is placed through the core musculature. Hubley-Kozy & Vezina (2002) and Vezina & Hubley-Kozy (2000) found that ≥60% maximal Voluntary Contraction (MVC) achieved core strength gains and under 25% MVC was aimed at stability and endurance. Further to this some studies suggest as little as 1-7% MVC is required to stabilize the spine (Lehman, 2006; Davidson & Hubley-Kozy, 2005).

My data may therefore suggest a level of MVC that is complimentary to game performance outcomes as a negative correlation. What level of MVC is required for on court movements is unclear and complex to investigate. The only true way to evaluate this is to take EMG data whilst the tests are being conducted and for movements during on court practice to better understand what muscles are doing during play. Although I do not yet have the resources to do this, I must at least acknowledge that some of my testing and subsequent data may not provide the full picture I seek. An additional note specific to basketball is core strength endurance testing is more difficult for taller players (Strand et al., 2014) but, taller players also have advantages in basketball, as evidenced in this study previously.

The link between core strength and endurance and basketball specific demands is limited within literature. Relating research in other sports may help to elucidate findings. Shinkle et al., (2012) looked at core strength and the measurement of power at the upper and lower limbs. This was achieved by using medicine ball throws forward, backward, left, and right in both static (controlling trunk motion) and dynamic (not controlling trunk movement) tasks and comparing these to standard physical tests of 1RM, CMJ and agility. Push press was also used to the transfer of forces through the core to the upper limbs. The authors found dynamic movement related more to performance than static and that 1RM squat was the best predictor. The stability or controlled throw is not reflective of sport specific movement. This question the much-used core endurance exercises like plank and side plank. Whilst core strength and endurance are believed to provide the basis for optimal use of the limbs, the link between these factors and performance is not clear. However, there is a tenuous link between core strength exercises and both upper and lower limb use in sport (Hibbs et al. 2008). Tse, McManus & Masters (2005) may question this as they found no link to support a link between core endurance and performance in a group of collegiate rowers.

My project looked for a stability test for the upper limb as much of the focus is on lower limb injuries in basketball, because this is where the highest incidence of injuries occurs. Closed Kinetic Chain Upper Extremity Test (CKCUEST) positively correlated with 3pt field goal percentage and was chosen as it tested stability, strength endurance and coordination of athletes (Tucci et al., 2014; Goldbeck & Davies, 2000). Key attributes like those mentioned in the previous paragraph apply here to the CKCUEST. Transferring strength form the upper limbs and core to the extremities during technical movements like the 3pt field goal requires strength, endurance, coordination neuromuscular control that ties in with the technical model. Correlation with CKCUEST and 3 pt field goals is a logical outcome as a player's ability to control movement variables and maintain height of release that requires strength and control are fundamental elements of shooting the 3pt field goal (Clemons et al., 2010; Tran & Silverberg, 2008; Okazaki et al., 2015). CKCUEST demands control of the torso whilst an accurate and quick placement of the hand across to the opposite hand. The strength and stability required for the task are also needed for shooting, so some cross over can be seen even though there is no direct functional position relating to basketball. CKCUEST has provided a more challenging, time efficient and functionally relevant test for me to take forward as part of my screening protocol, as it appears to relate to control aspect of ball control, shoulder and core stability needed for good shooting mechanics.

Any opportunity to provide EMG analysis alongside testing will help to progress my understanding of not only my testing protocols but also my athletes. This is beyond my resources at this time but changes I have made are the inclusion of CKCUEST and to retain the side plank for strength endurance asymmetrical comparisons. This provides me with some fundamental data and one test that has, at least in this study, had positive correlation with performance outcome, namely the 3pt Field Goal.

Core Strength Endurance and Stability Correlations with injuries.

At the time the testing was done expectations were that some tests would correlate with injuries. However, upper limb injuries were minimal as previously stated therefore any correlation or link with or toward an upper limb stability test would be unlikely to be found. Research has identified athletes with shoulder issues perform poorer on CKCUEST and showed a correlation to injuries of the shoulder bilaterally (Sciascia & Uhl, 2015; Pontillo et al.,2014). No correlations were found with any of the core strength endurance tests, that again may be due to where most injuries occur in basketball, our strength and conditioning programme and possibly our style of play.

(5) Agility and Speed

Agility, Speed and Aerobic Correlations with Game Performance Outcomes.

The physiological demands of basketball have been clearly identified within the literature and none are more relevant to the sport's specific movements than agility, speed and change of direction (Ben Abdelkrim et al., 2007; McInnes et al., 1995; Scanlan et al., 2011; Torres-Ronda et al., 2016). I considered agility testing with a clear understanding of wanting to use a standard test for a comparison (Agility T-Test) and to use similar tests with a reactive and non-reactive component, so I can better understand the athletes' perceptual abilities to aid future training.

Agility T-Test is used by my academy, GB national teams and across basketball AASE programmes. One of the concerns raised with this test is that it has no perceptive or decision-making element (Spiteri et al., 2015). Therefore, it is thought less likely to relate closely to game play but is recognised has more similar movement patterns associated with basketball using lateral shuffle (Delextrat & Cohen, 2008). Agility T-Test had a series of negative correlations that display a quicker T-test leads to greater performance on court, resulting in increased number of games played which, provides a greater opportunity to perform. Moderate negative correlations with number of games, defensive rebounds and total point in a season provide us with a clear indication the importance of change of direction and speed.

This seemingly strong relevance of the T-Test must not be underestimated, but my finding of no correlations between reactive agility test and game performance outcomes was surprising. The reactive agility test was designed to have decision-making relevance and therefore correlate with performance. The explanation for these findings is the reactive agility test does not have basketball specific movements and is apparently unable to relate to game play required movements, even though it was set up to reflect distance on court. If I compare this to the T-Test this may be the critical difference, as previous studies have highlighted the importance of sport specific movement built into testing (Moorland et al., 2013; Sekulic et al., 2014; Spasic et al., 2015). Spasic et al. (2015) implemented a reactive and non-reactive test for handball but only had a choice of two directions to move for decision-making. I felt this did not replicate adequately the number of options on court so used four gates, but in doing so was not able to get enough sport specific movement into the test. However, it would be foolish to assume that the test did not provide valuable information.

The reactive agility test was performed quicker than non-reactive agility. Previous research would suggest this was unexpected as a pre-determined route is thought to be quicker due to the athlete knowing what is coming rather than having to react (Spasic et al., 2015). Having watched this process, the interpretation of results is the stimulus of the reactive tests provided an incentive or motivation for players. Players were clearly driven by the light stimulus and appeared to work harder. This is in keeping with research suggesting a stimulus aids performance (Young et al., 2015).

Understanding and interpreting the success of the T-Test coupled with the information drawn from reactive testing enables me to move forward in developing agility testing within my academy setting to be more movement specific, combined with a reactive perceptual element. This will be basketball movement, as in the T-Test, but with more directions and a reactive element. The continued search of a highly relative reactive and perceptual test will be a priority from this study. Both myself and the academy strength and conditioning coach have 3 protocols that will be tested across the next two years and incorporate three key elements identified as essential: 1. Basketball specific movement (lateral shuffle), 2. A perceptual and decision-making component, 3. Multiple reactive choices with stimulus.

The ability to move at speed over short distances is essential in basketball. As most movements in basketball are under 10m in distance regardless of level (Scanlan et al., 2011; Scanlan et al., 2014). The 5m sprints had a strong negative correlation with assists season average. This indicates the faster you are over 5m the higher the average of assists you achieve. From my testing only one of the three sprint distance tests showed correlation. I would argue the need the need for basketball sport specific movement and relevant distance to be involved in testing more akin to the 5m test as this more closely mimics on court movements. Furthermore, a greater understanding of differences in physical requirements and not just physical attributes for individual positions is needed. For example, I want all players to have a broad range of physical attributes, but a guard is always expected to be quicker than a centre over a short distance.

The implication in my applied practical setting is to use the reliability of the T-Test and the value of the reactive agility test and work through pilot testing to develop one test that allows me to have basketball specific movements, and a comparison between reactive and non-reactive abilities. The process of developing a test will fundamentally have an emphasis of direction and distance, with basketball specific movement at its core. Starting with the T-Test I will look to add in more directions providing greater perceptual and decision-making elements to the test. A key part to include here will be the test still requires non-reactive element. What angle each direction is form the centre point and if return to a start point will become part of the process of development. Tests will be aligned to include the three key elements outlined earlier in this section. The short sprint test has shown limited value when compared to standard testing of 10m and 20m but will be used for physical comparison data, not related to game performance outcomes.

Agility, Speed and Aerobic Correlations with injuries.

As with a general pattern of findings from my project, no correlation was found between injuries, agility and speed.

(6) Jump Tests and Reactive Strength Index

Jumps Test Correlations with Game Performance Outcomes.

Arguably the most surprising statistic was that no jump testing correlated with any performance outcomes. Understanding basketball specific demands led me to hypothesize that correlations would be found with game performance markers like rebounding and blocked shots as identified by Ziv & Lidor (2009). I had through pilot testing narrowed the amount of jump testing to be included to reduce the number of variables to a manageable amount and selected the jump tests with greatest performance and relevance. No difference was found in playing position and vertical jump ability. This is the same reported outcome as Ostojic et al. (2014). One other paper has found correlation between playing position and jump performance, but this is not a consistent pattern on counter movement jump evidence (Latin et al., 1994).

A recent paper published after I had completed our testing found that both running jumps and repeated jumping were a better measure of performance outcomes

(Pehar et al., 2017). Consideration was given to include running jumps but a valid way to measure with minimal equipment was not found. One key aspect of this research is that testing must be affordable and accessible in a practical way. Like Pehar et al. (2017) we did test repeated jump with four consecutive jumps compared to their six. The number of jumps could make a difference, but the Just Jump mat has a set protocol of four jumps. Further to this, Pehar et al. (2017) measured Reactive Strength Index (RSI) from a box drop jump, compared to this study from the floor off the Just Jump mat. Aside from differences in types and application of tests, Pehar et al. (2017) also had 110 participants compared to our 19.

I have strived to apply functional testing related to game specific demands. It appears in relation to jump testing this was not achieved. A re-evaluation of how we can measure basketball specific jump movements, especially running jumps, needs to be completed and tested against game performance outcomes. This is most likely to include video recording and varied take off lines toward a backboard, as other equipment will prove unaffordable. I also must consider how opponents affect the outcomes of jump related situations during game play. Changes to my practice will be to consider how I develop jump tests and validate not only the test but explore the performance of the test to the game performance outcomes.

Jumps Test Correlations with injuries.

The lack of correlations found between jump testing and injuries may be less about the jump height and more about the landing mechanics. This is an element that requires video recording. Presently, if a player lands on an opponent's foot sustaining an injury that video clip would be analysed. A step forward for practice within the academy setting is to analyse the jump landing mechanics of all players. Current analysis of players is only undertaken if they present with injuries to the academy physiotherapy clinic. The group of players' performances on testing did not have great variation between left and right (≤1cm) so show a relatively well-balanced and conditioned group. No research to date has linked asymmetry with injuries in jumping and basketball.

Overall Injury Discussion

Limited correlations with injuries are most likely due to two key points; 1. We had low numbers of injuries and participants. 2. We already have implemented a prehabilitation protocol that incorporates injury prevention and neuromuscular training that could not be justified in removing due to increase injury risk. Neuromuscular training has been found to be effective at injury prevention by two systematic reviews, provided it is applied for more than three months (Herman et al., 2012; Hubscher et al.,2010).

As an academy staff member, I believe the protocols that I put in place five years ago have contributed to very low injury numbers in both our basketball academy and wider multi-sport academy. The academy injury rates have been in 2016/17, 68 for all sports, and 20 in basketball. In 2017-18, 50 for all sports, and 16 for basketball. In 2018/19, 51 for all sports, and 20 for basketball. At our academy not all load is recorded for all sports and the number of athletes across sport programmes fluctuates, ranging for the academy as a whole between 90-120 athletes. In a general sense, the basketball athlete will train for two hours per day and compete in games twice per week. In addition to this basketball players will have a minimum of two strength and conditioning sessions per week and two individual sessions per week.

These injury numbers are low considering the demand placed upon players, and within this study stands at 1.1 injuries per basketball player. It should be noted that some injuries are more time loss injuries than others and the rate of injury does indicate the impact of injuries on the player or team. The protocols include inhibition, lengthening, single leg neuromuscular control, dynamic movement, and cognitive strategies, alongside a comprehensive strength and conditioning programme similar to those indicated as requirements by Herman et al. (2012). Academy pre-hab protocols have developed over some years. All our prehabilitation work has both a generic and individualised component. The latter is based on the screening that has taken place. Our strategy is to work through 5-6 mobility exercises followed by a phase of inhibition where we predominantly utilise foam rollers. Once inhibition has taken place dynamic lengthening in a slow controlled manner across specific muscle groups is phase 2. Phase 3 is activation concentrating on 'switching on' muscles in preparation for training and phase 4 that is the integration of basketball specific movements and usual training warm up. Across the last season and a as response to some learning from this study, we have further introduced some key generic exercises for injury prevention and assigned each athlete to either a hip/groin, knee, or ankle group, again based on the screening and testing assessment by the sports medicine team. Prehabilitation is completed by all players before every training session and game. Post training and games players will go through a cool down routine that works from active recovery tip to toe static stretch.

Ongoing monitoring of injuries and the protocols we use to reduce them are tied to the screening and testing that highlights potential areas of focus for preventative work. Part of this process is to understand the links between on court basketball specific movements and focusing on the type and area of injury. How I look to address deficiencies across a team will only carry so far. An individualised approach is required to fully understand each players deficit to both injury and performance. The two are intrinsically linked. Although my current practice has provided good outcomes, further changes to this to include enhanced ankle prevention strategies and postural activation are set to be included.

The academy aim is not only to improve performance and reduce injuries but also to develop well-rounded basketball players from a physical perspective and ultimately provide a pathway for basketball and education be that in the UK, Europe or North America. The injury rates at the academy highlight to me the discrepancy in rate of injuries for basketball compared to the whole of the academy. It is true the basketball academy places greater demands on athletes and is elite, which is why I must move forward in developing with coach's measurement of load to see where improvements can be made to reduce injuries. Factors that are more difficult to influence and control should also be considered. Among these are lifestyle elements that are hard to monitor and change unless adherence is strong. This includes the players recovery post training and games, their nutritional intake and critical timing of replenishing, and sleep patterns. Injury is at times influenced by the opposition so this review with coaches across styles of play where injuries may be greater than our average should be discussed broader than the video clip for an injury sustained,

Multiple Linear Regression Analysis.

Model 1.

Model 1 took a logical approach in attempting to understand if active movement at multiple joints, as would be the case during on court play, have a bearing on 2pt Field Goal Percentage Season Total. Players use multiple joints from upper and lower limb to execute 2 pt field goals. We did expect to find a strong influence of 2pt field goals from these parameters however, the small sample may mean the true interaction through this model is difficult to fully understand. Although most significant correlation from both upper and lower limb variables were from passive tests, passive movement does not relate as strongly to on court demands by the player. This is not to say it does not have a bearing on performance, but no part of a 2pt field goal attempt is a passive movement. We did consider running a similar analysis with passive upper and lower limb ROM tests and 2pt field goals but felt this was more of a fishing expedition and not based on logic aligned to game and basketball demands. However, model 2 does consider passive movements.

Model 2.

Model 2 was developed based on positive correlations with lower limb passive parameters. The models dependent variable of free throw percentage season average and independent variables of right and left dorsiflexion passive left and right hamstring 90/90 and left and right straight leg raise were found to be significant proportion in the in the variation for Free throw Percentage Season Average F (6,12) = 3.163, $p < .005$. Of the independent variables the Left Hamstring 90/90 was the strongest predictor with a significance value of .045. The construction of this model was based on the correlation results of both the dependent and independent variables. The only variable with a significant value in this model (Left Hamstring 90/90) is also the only variable to have a correlation with the independent variable in the correlation analysis. This may be an anomaly and again influenced by low numbers of participants, but it may be due to a lesser degree of movement on this test produces stronger outcomes for the dependent variable. Free Throw percentage Season Average was chosen over Free Throws Made as the latter is influenced by how many are taken.

Model 3.

Model 3 combined moderate to strong correlations of passive ankle range of movement, agility tests and sprint test to the dependent variable of Assists Season Average. The independent variables of 5M sprint, left and right dorsiflexion passive, reactive and non-reactive agility test and agility T-test showed a significant proportion in the total variation in Assists Season Average with a significance level for the model at .006. However, only one independent variable, 5M Sprint, showed a level of significance (.001). 5M Sprint unstandardized coefficients B value is minus (-9.445) which is reflective of the direction we expect to see. i.e., The shorter the time, the quicker the athlete. Sprint time has a cross over on court to agility which is why it is showing as the dominant predictor. 5M sprints are not often researched and used in testing but, our findings suggest a greater applicability to on court performance outcomes.

Model 4.

Similar to Model 3, Model 4 combined correlations of passive ankle range of movement, agility tests and sprint test to the dependent variable of Steals Season Average. The independent variables were chosen and collated for this model for two reasons. Firstly, for correlation to the dependent variable and secondly, they are factors in achieving steals in games play, meaning a quickness of speed and rection is required. In this model no prediction of steal season average can be aligned to the variable in this model. The usual caveat to low numbers applies but it is also worth noting the comments on further development of the reactive and non-reactive agility tests.

Implications for practice and experiential learning points.

The driving force behind this study was to inform, refine and change the practice of my academy athlete screening in basketball. It was a critical requirement for me to understand why I am using tests and ensure I choose the correct tests. Selection of correct tests has in many ways through this process been my way of elimination and discovery combined. The outcomes of the project have and will continue to inform my practice.

What has become repeatedly evident across many types of tests and outcomes is the need to fully engage with, and understand, the variables we as Sport Science Exercise Medicine (SSEM) staff need. This should be inclusive of how the players are coached, what key attributes the coach seeks, and what style of play they have that may influence statistical outcomes or the physical characteristics a player may require. As I have previously stated, the need to analyse on court movement with video alongside coaches and to interpret how an athlete moves is an important step. If a controlled test is going to inform us of any changes to make this movement better or more efficient the test should be considered for inclusion. From this point I am able to work collaboratively with the academy staff and pilot test to see if testing can be moved to a position where sport specificity is incorporated into the screening test.

Furthermore, my understanding of basketball has been enhanced greatly having worked with national teams in 127 international games. However, this is still not enough to apply knowledge to a specific situation or movement requirement on court. Greater interpretation of what I observe will enable me to evaluate exactly effectively leading to more informed decisions on preparation, screening tests and injury prevention. An example of this may be what I see as slow foot speed on the initial two steps. My interpretation of this is slowness of the player, but in fact the cognitive and perceptual aspect need to be considered here. Only by looking at the complete context of the on-court situation can I bring together tests that reflect real game play situations. One further example already mentioned in the jumps section is worthy of a final reminder. None of the jump's protocols found correlation with game performance outcomes. When looking at game play the ability to jump with forward motion is more common than static vertical jumping. To develop a test inclusive of forward momentum is crucial if I am to progress jump related testing.

Changes to practice must include video analysis of all injuries and of individuals undertaking basketball specific movements like lay ups, jump landing mechanics, and change of direction. Playback observations will allow me to identify individual biomechanical insufficiencies and alignment optimization. It is possible analysis can be taken a step further. Using Electromyographic (EMG) data during training on movement specific to basketball will provide the SSEM team with more knowledge in tailoring programmes to improve performance, and potential performance in our athletes. Depending on what area or movement is being analysed, EMG pads are placed onto body regions to further understand muscle activity and to evaluate what changes there are in muscle activation and compensation patterns for specific movements on court. EMG will provide me with more information on what a test may or may not show me. EMG inclusion will be a significant step, but more detailed information is needed if I am to take testing further in a sport specific direction with a meaningful purpose.

The immediate impact for applied practice is clear for in test groups and an ongoing process of development for other test groups. Value in baseline data range of motion screening remains, although refinement to use active testing will make screening more efficient. Jump testing must include a running test that is most likely to be videoed for post testing analysis. This moves the academy toward a sport specific jump test aside from the lower limb power CMJ test that is currently used. Upper limb testing will change from the light 3kg med ball throw long sitting to 9kg 45° bench sitting. This provides the academy with a more applicable and robust test for our level and the physical ability of the athletes.

Agility testing is a fundamental area for basketball and one I will continue to develop at the academy. The T-Test needs to be developed so it has a reactive and non-reactive element and a greater number of choices to make. The stimulus of reactive testing showed us how providing a stimulus leads to greater effort, so I am currently devising further agility testing protocols to trial. This will be a process through stages because we require a season of game performance data it may take some years before we arrive at a sport specific test that provides us with relevant information.

A better set of more applicable applied testing tied to key performance indicators will enable me to correct throughout training, rather than primarily focus on the technique of the test. Technical correction is applied already so a clear agreed group of technical objectives now need to be explained and collaborated on with the coaching staff. Clear technical objectives can help us to 'sell' tests to coaches that buy us time in applying our practice especially in national team environments where time is a precious commodity. An example of this would be to include skills-based ball work within physical tests like agility. Testing with and without the ball allows staff to see how players move on ball and off ball that is more closely aligned to training and game movement requirements, which is noted by coaches at all levels. In addition to technical specificity inclusion to agility testing, considering repeated agility testing in testing protocols is important to reflect the physiological demands of basketball noted earlier in the paper. Repeated agility testing in rugby league has been shown to have significant correlations between repeated Illinois agility test (RIA), repeated T-agility test (RTT) and baseline fitness measures inclusive of CMJ, 30m sprint, single effort agility and repeated sprint ability (Nicholls et al., 2020). The validity of the Repeated Modified Agility Test (RMAT) has been established by Haj-Sassi et al., (2011) and shows good correlations with three jump tests as a comparison of anaerobic power and the Wingate test. Anaerobic power and the ability to produce repeated bouts of exercise at high intensity are essential components of basketball as is a change of direction with acceleration and deceleration. The agility required in basketball is therefore slightly different compared to other sports where COD is often a fluid movement as oppose to a start stop motion. Integration of repeated testing will be developed within our testing protocols.

The challenge with incorporating closer sport specific movements is that sight is not lost on the purpose and objective of the test itself. If testing is to be maintained in some form, I must ensure I measure what I set out to measure. Too sport specific will lead to training scenarios with tests interspersed that will be of little value to the player for individual athlete development.

A key learning point from the application of this study was the difficulty in fitting all the testing of athletes into the defined slots. If I consider athletes curriculum, injuries, and other family and academic commitments, having purely comparable data delivered at pre-defined times is a challenge. I must recognise at times this is not possible and understand it is not likely to skew results unless significant delays become apparent. Data collected will still need to be presented with relativity to on court performance, as coaches will ask what the results mean and how do they translate to basketball. Incorporating testing into training using video does not interrupt training and will mean more post session analysis but has great potential to provide more detailed understanding of movement for us to improve players physically and for coaches to improve them technically. Developing this theme of the reality of testing brings us to the low numbers of participants. Within the academy and attached basketball club we have access to a wide range of athletes. Finding a statistical method that can equalise different levels of competition and make testing comparable across age groups will provide greater statistical power. With a more efficient and sports specific screening testing protocol the data becomes more manageable and applicable.

The results of the study have made me consider how I interpret my observations. Agility test outcomes are just one example of this with the development of further test protocols already identified. Jumps test protocols needs to be further developed to incorporate forward motion, and changes to upper limb tests and differentiating active and passive range of motion testing are further examples of changes to practice. The process has taught me to review and ask questions more searching than I would have before the project commenced, when working through an autoethnographic piece of work relating to my current practice at the time. It has made me think more deeply about interpreting outcomes as oppose to a previous linear thought process. It allows me to expand and take this research forward building partnerships with university sports science, sports therapy, and physiotherapy programmes, integrating and introducing students to screening protocols. Recent examples of this is the introduction to screening for sports therapy students placed at our basketball club. They ran through a screening protocol for both U16 and U18 boys' teams, that included video analysis of running, range of motion testing and SCAT 5 testing for baseline concussion. These collaborations enhance what the club can deliver to its players, but more importantly greatly enhance the skill set sports therapy students have with a stronger understanding of screening and it is specificity to ages and levels.

Learning to manage variation in players within data is challenging. In applied practice we adapt and cope with 'outliers', but within data we extract them. For me in an applied setting we may have a fifth of players over 6' 8" and one at 7' 2", so removing them from data proves problematic with the relatively small number we have. Learning to manage the data and be able to interpret and accept anomalies is an important skill that has developed across this process of study.

The balance between scientific rigor and real-world application is fascinating. I have always driven to be an applied practitioner, as it has enabled me to build stronger relationships with coaches. The struggle is when practice and science contradict one another. Using evidence to guide you where evidence is present, but not being overwhelmed to challenge the evidence. Taking on the role in an applied setting, as I have, and finding answers in whole, or at least in part, if no evidence exists has helped to bridge the gap between science and evidence and the applied setting. In considering reactive versus non-reactive agility, within the literature non-reactive is deemed to have greater or quicker performance. However, my athlete’s reaction to a stimulus was greater when compared to other studies. Bridging the gap between my project results and current research takes interpretation and not a literal look at numbers. Another example referred to in the previous paragraph are the outliers. If I remove one or two ‘bigs’ from the study does that affect rebounds in game statistics? If I remove one or two of my smaller more agile guards does that affect agility and sprint results? The context of applied practice in my environment must take precedence if I am to continue to have trust, time, and respect of coaches.

A further aspect of this study is how the learning and processes from academy work is utilised with national teams in preparation for European tournaments. New challenges exist in the national team environment due to time restrictions, but a higher caliber of player usually creates a greater level of commitment. For 2019 agreed testing protocols with the head coach and strength and conditioning coach will, incorporate simple cognitive and reaction tests during training for the first time. My Professional Doctorate has informed these changes by the link between test results and game performance outcomes. This clear link is powerful in a performance environment where the result is the most important factor. It has also provided an objective piece of work related directly to what we do, play basketball. The stronger link is that some of our athletes are also GB players who will be able to explain the processes to other players, as I implement them during the summer.

Limitations and future research.

There are several limitations of the present study. First, the sample size could be considered relatively small. This affects the statistical power of the analyses. Specifically, small effects may not have been detected (i.e., were not statistically significant) (Saks & Allsop, 2019; Field, 2018). One way I used to help overcome this issue was instead focus on the size of effects (in combination with significance). When doing so, I was able to detect large effects, which are likely the most meaningful in applied practice (as in the present study) (Arts, van der Akker & Winkens, 2014). Second, numerous statistical tests were conducted. This increases the chance of Type I error (rejecting the null hypothesis when it is in fact true). There are several ways to deal with Type I error, including adjusting the alpha level (i.e., adjusting the *p* value criteria for significance); one such approach is the Bonferroni correction (Field, 2018). However, such methods are extremely conservative in that they can make even large (and meaningful) effects nonsignificant, meaning that effects with real world significance are missed (Armstrong, 2014; Perneger, 1998). Consequently, I decided to focus on a balance between statistical significance and real world meaning, as such I did not adjust the alpha level for the present study (Armstrong, 2014; Perneger, 1998). Third, inevitably some data was missing because of player injuries. I do not think this affected the data as statistical methods were used to nullify this but given the small number of participants this is a consideration of inclusion criteria to reduce loss of data from injury. I have been conscious throughout the study to try and ensure it was run according to academy life. Inevitably athletes will have some inability to attend sessions or miss games due to injury. As an academy team I cannot recruit more participants, as this would not reflect our real-world working environment and situation.

More in-depth statistical analysis was considered but due to the small sample size was not deemed suitable for this study. Factor analysis could be a useful tool with adequate participants and would be considered to aid in dimension reduction, thereby providing a possible route to understanding tests with poor efficacy and that are less likely to indicate relevance to game performance outcomes or injury risk.

My Professional Doctorate is about basketball. Basketball is said to reach parts of society other sports cannot reach (Basketball All-Party Parliamentary Group, 2014; House of Commons Library, 2018). In my experience the diversity of just our academy would suggest this is correct, then we must consider players individual background, social economic status, and lifestyle. Secondly, I did not map injuries to load, nor is it mapped to injuries per 1000 hours that is the most widely recognised sports injury incidence method (Hodgson Phillips, 2000). Load is important as it allows us to subjectively understand the demands placed on players using RPE (Foster et al., 2001; Haddad et al., 2017) as we do not have access to GPS or accelerometer devices. These are the next steps to help me understand where I can improve the quality of performance and life of my young athletes. From the 2019/20 season the academy introduced load monitoring using RPE, and minutes for both athletes and coaches. Further to the load monitoring I will record injuries based on the per 1000 hours system. Validity of my screening tests is essential and can be strengthened through consistent gathering of data. This will allow me to understand natural variability and not make errors of judgement based on minimal data. With daily screening this is a key point that also applies, to in season screening as it does in daily markers. My single test protocol cannot look at change across time, which is a significant shortcoming when considering how to update and adapt training programmes.

Equipment also becomes important when considering the tests, we use. Measuring repeated physical parameters like sprints or jumps are more reliable with technology. Movement toward what may be deemed closer to game play is inevitable, but I acknowledge at this time is a limitation. Given the research outlined in the literature review section under the sport physiology section, it may be that we develop a way to measure physical parameters beyond the physiological markers well detailed within current research during training, as this appears to provide at least equal outcomes in players physical development.

Chapter 6 Conclusion.

Physical screening and testing provide information that relates directly to basketball performance outcomes. It is not yet clear exactly what the information is, but there are correlations found between screening tests and basketball game performance outcomes. Therefore, my experimental hypothesis for this thesis that useful screening tests would correlate with selected game performance metrics is accepted and proven. Although I found correlations between screening tests and basketball game performance outcomes the information and detail as to where the links are in terms of sport specific movement and elements like muscle activation are yet to be explored. The testing protocol helped to identify screening tests that provide no additional information and as such are seen as no longer efficient to apply. Those tests are Range of Motion tests that have previously been applied both actively and passively. Other than if a test is passive, all Range of Motion tests will now be applied actively. Jump testing was found to have no relationship to basketball game performance outcomes and will in my academy setting be used for lower limb power tests only. Therefore, I will further develop jump testing with forward motion to reflect the basketball game movement dynamics in partnership with my strength and conditioning coach. Agility testing has informed me that the academy basketball athletes require a perceptive and decision-making element to agility testing combined with basketball specific movements. Combining the sport specific movement of Agility T-Test with a greater number of directions to move and a reactive component will be the focus of a new agility test.

Athlete screening in basketball and specifically in our academy setting will develop by eradicating non informative tests and further develop some tests that provide an indication that refinement of the test will yield better links and information on game performance outcomes. My study has highlighted the need to use tests that mimic as near as possible basketball specific movements, analyse biomechanical alignment and use of video to review and improve. Video review and analysis will be done in conjunction with coaches to ensure a technical input and understanding is present.

Future research should focus on how to measure and compare sport specific movements like the running jump and reactive agility test so physiotherapists can ensure screening tests provide a clear relationship to game performance outcomes, thereby providing valuable information to coaches and SSEM staff alike. Secondly, understanding how we can utilise greater information on not only playing position but the role within this based on coaches demands. Thirdly, the use of ENG during screening and training will provide vital information on patterns of muscle activity specific to basketball, each player and deliver a greater detail alongside our screening and more sport specific drive.

Chapter 7

Conflicts

The author has no conflict of interest. No funding assistance was provided for this project.

References

Abdelkrim, N.B., Castagna, C., Jabri, C., Battikh, I., El Fazza, S. & El Ati, J. (2010). Activity profile and physiological requirementsof junior elite basketball players in relation to aerobic-anaerobic fitness. *Journal of Strength and Conditioning Research,* 24, 2330-2342.

Abdelkrim, N.D., Chaouachi, A., Chamari, K., Chtara, M. & Castagna, C. (2010). Positional role and competitivelevel differences in elite-level men's basketball players. *Journal of Strength and Conditioning Research*, 24, 1346–1355

Abernethy, B., & Wood, J.M. (2001). Do generalized visual training programmes for sport really work? An experimental investigation. *Journal of sports sciences, 19*, 203-222.

Abernethy, B. & Russell, D.G. (1987). The relationship between expertise and visual search strategy in a racquet sport. *Human Movement Science*, 6, 283-319.

Alemany, J.A., Bushman, T.T., Grier, T., Anderson, M.K., Canham-Chervak, M., North, W.J. & Jones, B.H. (2017). Functional Movement Screen: Pain versus composite score and injury risk. *Journal of Science and Medicine in Sport, 20*, S40-S44.

Alenezi, F., Herrington, L., Jones, P. & Jones, R. (2014). Relationships between lower limb biomechanics during single leg squat with running and cutting tasks: A preliminary investigation. *British journal of sports medicine, 48*, 560.

Almangoush, A., Herrington, L. & Jones, R. (2014). A preliminary reliability study of a qualitative scoring system of limb alignment during single leg squat. *Physical Therapy and Rehabilitation, 1*, 2.

Altmann, S., Hoffmann, M., Kurz, G., Neumann, R., Woll, A. & Haertel, S. (2015). Different Starting Distances Affect 5-m Sprint Times. *Journal of strength and conditioning research, 29*, 2361-2366.

Andreoli, C.S., Chiaramonti, B.C., Biruel, E., de Cstro Pochini, A., Ejnisman, B. & Cohen, M. (2018). Epidemiology of sports injuries in basketball: integrative systematic review. BMJ Open Sport & Exercise Medicine, 4, -19. doi:10.1136/ bmjsem-2018-000468

Arampatzis, A., Schade, F., Walsh, M. & Brüggerman, G-P. (2001). Influence of leg stiffness and its effect on myodynamic jumping performance. *Journal of electromyographic and kinesiology*, 11, 355-364.

Armstrong, R.A. (2014). When to use the Bonferroni correction. *Opthalmic & Physiological Optics,* 34, 502-508.

Arora, C., Singh, P. & Varghese, V. (2021). Biomechanics of core musculature on upper extremity performance in basketball players. *Journal of Bodywork and Movement Therapists*, https:// doi.org/10.1016/j.jbmt.2021.02.023

Arts, S., van der Akker, M. & Winkens, B. (2014). The importance of effect sizes. *European Journal of General Practice,* 20, 61-64.

Askling, C., Saartok, T. & Thortensson, A. (2006). Type of acute hanstring strain affects flexibility, strength and time to return to pre-injury level. *British Journal of Sports Medicine,* 40, 40-44.

Atkin, K., Herrington, L., Alenezi, F., Jones, P. & Jones, R. (2014). The relationship between 2D knee valgus angle during single leg squat (SLS), single leg landing (SLL), and forward running. *British journal of sports medicine, 48*, 563.

Atkinson, G. & Batterham, A.M. (2015). True and false inter-individual differences in the physiological response to an intervention. *Experimental Physiology,* 100, 577-588.

Backman, L.J. & Danielson, P. (2011). Low Range of Ankle Dorsiflexion Predisposes for Patellar Tendinopathy in Junior Elite Basketball Players. *The American Journal of Sports Medicine, 39*, 2626-2633.

Bahr, R. (2016). Why screening tests to predict injury do not work-and probably never will...: a critical review. *British journal of sports medicine, 0,* 1-6.

Ball, N.B., Stock, C.G. & Scurr, J.C. (2010). Bilateral contact ground reaction forces and contact times during plyometric drop jumping. *Journal of strength and conditioning research / National Strength & Conditioning Association, 24*, 2762.

Bangsbo, J., Iaia, F.M. & Krustrup, P. (2008). The Yo-Yo intermittent recovery test: a useful tool for evaluation of physical performance in intermittent sports. *Sports Medicine, 38*, 37-51.

Basketball All-Party Parliamentary Group (2014). Available at http://www.appgbasketball.org.uk/resources/APPGInquiryFinalReport.pdf (Accessed 16 July 2018).

Ben Abdelkrim, N., El Fazaa, S. & El Ati, J. (2007). Time-motion analysis and physiological data of elite under-19-year-old basketball players during competition. *British journal of sports medicine, 41*, 69-75; discussion 75.

Bencke, J. & Zebis, M.K. (2011) The influence of gender on neuromuscular pre-activity during side-cutting. *Journal of Electromyography and Kinesiology, 21*, 371-375.

Bennell, K., Talbot, R., Wajswelner, H., Techovanich, W., Kelly, D. & Hall, A. (1998). Intra-rater and inter-rater reliability of a weight-bearing lunge measure of ankle dorsiflexion. *Australian Journal of Physiotherapy, 44*, 175-180.

Beynnon, B.D., Murphy, D.F. & Alosa, D.M. (2002). Predictive factors for lateral ankle sprains: A literature review. *Journal of Athletic Training, 37*, 376-380.

Bird, S.P. & Markwick, W.J. (2016). Musculoskeletal screening and functional testing: considerations for basketball athletes. *The International Journal of Sports Physical Therapy, 11*. 784-802.

Borsa, P.A., Laudner, K.G. & Sauers, E.L. (2008). Mobility and stability adaptations of the overhead athlete: A theoretical and evidence-based perspective. *Sports Medicine*, 38, 17-36.

Bosco, C., Luhtanen, P. & Komi, P.V. (1983). A simple method for measurement of mechanical power in jumping. *European journal of applied physiology and occupational physiology, 50*, 273-282.

Boyd, B.S. (2012). Measurement properties of a hand-held inclinometer during straight leg raise neurodynamics testing. *Physiotherapy, 98*, 174-179.

Braun, S,. Kokmeyer, D. & Millett, P.J. (2009). Shoulder injuries in the throwing athlete. *The Journal of bone and Joint Surgery, 91*, 966-978.

Brughelli, M., Cronin, J., Levin, G. & Caouachi, A. (2008). Understanding change of direction in sport: A review of resistance training studies. *Sports Medicine, 38*, 1045-1063.

Brukner, P., White, S., Shawdon, A. & Holzer, K. (2004). Screening of athletes: Australian experience. *Clin J Sport Med,14*, 169-177.

Bucheit, M. & Rabbani, A. (2012). The 30-15 intermittent fitness test versus the Yo-Yo intermittent recovery test level 1: Relationship and sensitivity to training. *International Journal of Sports Physiology and Performance*, 9, 522-524.

Buchheit, M. (2010). Performance and physiological responses to repeated-sprint and jump performance. *European Journal Applied Physiology,* 110, 1007-1018.

Bullock-Saxton, J. (1988). Normal and abnormal postures in the sagittal plane and their relationship to low back pain. *Physiotherapy practice, 4*, 94-104.

Burr, J.F., Jamnik, R.K., Baker, J., Macpherson, A., Gledhill, N. & McGuire, E.J. (2008). Relationship of physical test results and hockey playing potential in elite-level ice hockey players. *Journal of Strength and Conditioning,* 22, 1535-1543.

Butler, R.J., Crowell , H.P. & McClay Davis, I. 2003). Lower extremity stiffness: implications for performance and injury. Clinical biomechanics, 18, 511-517.

Button, C., Macleod, M., Sanders, R. & Coleman, S. (2003). Examining movement variability in the basketball free-throw action at different skill levels. *Research Quarterly for Exercise & Sport, 74*, 257-269.

Cabarkapa, D., Fry, A.C. & Deane, M.A. (2021). Differences in kinematic characteristics between 2-point and 3-point basketball shooting motions - A case study. *Journal of Advances in Sports Physical Education*, 4, 19-23.

Carter, E.A., Westerman, B.J. & Hunting, K.L. (2011). Risk of injury in basketball, football, and soccer players, ages 15 years and older, 2003-2007. *Journal Athletic Training*, 46, 484-488.

Carvalho, H.M., Coelho E Silva, M.J., Figueiredo, A.J., Gonclaves, C.E., Castagna, C., Philippearts, R.M. & Malina, R.M. (2011). Cross validation and reliability of the line-drill test of anaerobic performance in basketball players 14-16 years. *Journal of Strength and Conditioning Research, 25*, 1113-119.

Castagna, C., Impellizzeri, F.M., Rampinini, E., D'Ottavio, S.D. & Manzi, V. (2008). The Yo-Yo intermittent recovery test in basketball players. *Journal of Science and Medicine in Sport, 11*, 202-208.

Cavar, M., Corluka, M., Cerkez, I., Culjak, Z. & Sekulic, D. (2013). Are various forms of locomation - speed diverse or unique performance quality. *Journal of Human Kinetics, 38*, 53-61.

Cejudo, A., Sainz, d.B., Ayala, F. & Santonja, F. (2014). A simplified version of the weight-bearing ankle lunge test: Description and test–retest reliability. *Manual therapy, 19*, 355-359.

Çene, E. (2018). What is the difference between a winning and a losing team: insights from Euroleague basketball, *International Journal of Performance Analysis in Sport,* 18:1, 55-68.

Chalmers, S., Fuller, J.T., Debenedictis, T.A., Townsley, S., Lynagh, M., Gleeson, C., Zacharia, A., Thomson, S. & Magarey, M. (2017). Asymmetry during preseason Functional Movement Screen testing is associated with injury during a junior Australian Football season. *Journal of Science and Medicine in Sport*, *20*, 653-657.

Charlton, P.C., Mentiplay, B.F., Pua, Y. & Clark, R.A. (2015). Reliability and concurrent validity of a Smartphone, bubble inclinometer and motion analysis system for measurement of hip joint range of motion. *Journal of Science and Medicine in Sport, 18*, 262-267.

Chmielewski, T.L., Martin, C., Lentz, T.A., Tillman, S.M., Moser, M.W., Farmer, K.W. & Jaric, S. (2014). Normalization considerations for using the unilateral seated shot put test in rehabilitation. *Journal of orthopaedic & sports physical therapy, 44*, 518-524.

Chorba, R.S., Chorba, D.J., Bouillon, L.E., Overmyer, C.A. & Landis, J.A. (2010). Use of a functional movement screening tool to determine injury risk in female collegiate athletes. *North American Journal Sports Physical Therapy, 5*, 47-54.

Clemons, J.M., Campbell, B. & Jeansonne, C. (2010). Validity and reliability of a new test of upper body power. *Journal of strength and conditioning research, 24*, 559-1565.

Cohen, J. (2008). Statistical power analysis for the behavioural sciences (2nd ed). New Jersey, Lawrence Erlbaum.

Coleman, E. & Dupler, T. (2004). Changes in running speed in game situations during a season of major league baseball. *Journal of Exercise physiology Online, 7*, 89-93.

Conley, K.M., Bolin, D.J., Carek, P.J., Konin, J.G., Neal, T.L. & Violette, D. (2014). National Athletic Trainers' Association position statement: Preparticipation physical examinations and disqualifying conditions. *Journal Athletic Training, 49*, 102-120.

Conte, D., Kolb, N., Scanlan, A.T. & Santolamazza, F. (2018). Monitoring Training Load and Well-Being During the In-Season Phase in National Collegiate Athletic Association Division I Men's Basketball. *International Journal of Sports Physiology and Performance*, 13, 1067-1074. DOI: 10.1123/ijspp.2017-0689.

Cook, G., Burton, L. & Hoogenboom, B. (2006a). Pre-participation screening: the use of fundamental movements as an assessment of function - part 1. *North American Journal Sports Physical Therapy, 1*, 62-72.

Cook, G., Burton, L. & Hoogenboom, B. (2006b). Pre-participation screening: the use of fundamental movements as an assessment of function - part 2. *North American Journal Sports Physical Therapy, 1*, 132-139.

Cools, A.M., De Wilde, L., Van Tongel, A., Ceyssens, C., Ryckewaert, R. & Cambier, D.C. (2014). Measuring shoulder external and internal rotation strength and range of motion: comprehensive intra-rater and inter-rater reliability study of several testing protocols. *Journal of Shoulder and Elbow Surgery, 23*, 1454-1461.

Cowley, P.M., Fitzgerald, S., Sottung, K. & Swensen, T. (2009). Age, weight, and the front abdominal power test as predictors of isokinetic trunk strength and work in young men and women. *Journal of strength and conditioning research, 23*, 915-925.

Cronin, J.B. & Templeton, R.L. (2008). Timing light height affects sprint times", *Journal of strength and conditioning research, 22*, 318-320.

Crossley, K.M., Zhang, W.J., Schache, A.G., Bryant, A. & Cowan, S.M. (2011). Performance on the single-leg squat task indicates hip abductor muscle function. *American Journal Sports Medicine, 39*, 866-873.

Crow, J.F., Pearce, A.J., Veale, J.P., VanderWesthuizen, D., Coburn, P.T. & Pizzari, T. (2010). Hip adductor muscle strength is reduced preceding and during the onset of groin pain in elite junior Australian football players. *Journal of science and medicine in sport, 13*, 202-204.

Cummins, C., Orr, R., O'Connor, H. & West, C. (2013). Global positioning systems (GPS) and microtechnology sensors in team sports: A Systematic Review. *Sports Medicine,* 43, 1025-1042.

Cumps, E., Verhagen, E. & Meeusen, R. (2007). Prospective epidemiological study of basketball injuries during one competitive season: ankle sprains and overuse knee injuries. *Journal Sports Science Medicine, 6*, 204-211.

Dallinga, J.M., Benjaminse, A. & Lemmink, K.A. (2012). Which screening tools can predict injury to the lower extremities in team sports?: a systematic review. *Sports Medicine, 42*, 791-815.

Davidson, K.L. & Hubley-Kozey, C.L. (2005). Trunk muscle responses to demands of an exercsie progression to improve dynamic spinal stability. *Archives Physical Medical Rehabilitation, 86*, 216-23.

Dawson, S.J. & Herrington, L. (2015). Improving Single-Legged-Squat Performance: Comparing 2 Training Methods With Potential Implications for Injury Prevention. *Journal of athletic training, 50*, 921.

Delahunt, E., Kennelly, C., McEntee, B.L., Coughlan, G.F. & Green, B.S. (2011). The thigh adductor squeeze test: 45 of hip flexion as the optimal test position for eliciting adductor muscle activity and maximum pressure values. *Manual therapy, 6*, 476-480.

Delecluse, C.H., Coppenholle, H. & Willems, E. (1995). Analysis of 100 meter sprint performance as a multidimensional skill. *Journal of Human Movement Studies, 28*, 87-101.

Delextrat, A. & Cohen, D. (2008). Physiological testing of basketball players toward a standard evaluation of anaerobic fitness. *Journal of Strength and Conditioning research, 22,* 066-1072.

Delextrat A. & Cohen D. (2009). Strength, power, speed, and agility of women basketball players according to playing position. *Journal of Strength Conditioning Research,* 23, 1974-1981.

Delextrat, A., Grosgeorge, B. & Bieuzen, F. (2015). Determinants in performance of a new test of planned agility for young elite basketball players. *International Journal of Sports Physiology and Performance*, 10, 160-165.

Devlin, L. (2000). Recurrent posterior thigh symptoms detrimental to performance in rugby union. *Sports Medicine, 29*, 273-287.

Dhillon, M.S., Garg, B., Soni, R.K., Dhillon, H., Prabhakar, S. (2012). Nature and incidence of upper limb injuries in professional cricket players a prospective observation. *Sports Medicine Arthroscopy Rehabilitation Therapy Technology*. 4, 42-46.

Dick, R., Sauers, E.L., Agel, J., Keuter, G., Marshall, S.W., McCarty, K. & McFarland, E. (2007). Descriptive epidemiology of collegiate men's baseball injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2003-2004. *Journal Athletic Training,* 42, 183-193.

Dill, K.E., Begalle, R., Frank, B., Zinder, S.M. & Padua, D.A. (2014). Altered knee and ankler kinematics during squatting motion in those with limited weight-bearing lunge ankle dorsiflexion range of motion. *Journal of Athletic Trainer*, 49, 723-732.

Dix, C., Logerstedt, D., Arundale, A. & Snyder-Makler, L. (2020). Perceived barriers to implementation of injury prevention programs among collegiate women's soccer coaches. *Journal of Science and Medicine in Sport,* https://doi.org/10.1016/j.jsams.2020.09.016

DiStefano, L. J. DiStefano, Mi.J. Frank, B.S.Clark, M. A. & Padua, D. A. (2013) Comparison of Integrated and Isolated Training on Performance Measures and Neuromuscular Control. *Journal of Strength and Conditioning Research*, 27, 1083-1090.

Drakos, M.C., Domb, B., Starkey, C., Callahan, L. & Allen, A.A. (2010). Injury in the national basketball association: a 17-year overview. *Sports Health: A Multidisciplinary Approach, 2,* 284-290.

Drezner, J.A. (2003). Practical management: hamstring muscle injuries. *Clinical Journal of Sport Medicine,13*, 48-52.

Dupont, G., Defontaine, M., Bosquet, L., Blondel, N., Moalla, W. & Berthoin, S. (2008). Yo-Yo intermittent recovery test versus the Université de Montréal Track Test: Realtion with a high intensity intermittent exercise. Journal of Science and Medicine in Sport,

Earl. J.E., Hertel. J. & Denegar, C.R. (2005). Patterns of dynamic malalignment, muscle activation, joint motion, and patellofemoral-pain syndrome. *Journal Sport Rehabilitation*,*14*, 216–234.

Ebben, W.P. & Petushek, E.J. (2010). Using the reactive strength index modified to evaluate plyometric performance. *Journal of strength and* *conditioning research / National Strength & Conditioning Association, 24*, 1983.

Ekstrom, R.A., Donatelli, R.A. & Carp, K.C. (2007). Electromyographic analysis of core trunk, hip, and thigh muscles during 9 rehabilitation exercises. *Journal of Orthopaedic & Sports Physical Therapy, 37*, 754-762.

Ellenbecker, T., Manske, R. & Davies, G. (2000). Closed kinetic chain testing techniques of the upper extremities. *Orthopaedic Physical Therapy Clinics of North America, 9*, 219-230.

Engebretsen, A.H., Myklebust, G., Holme, I., Engebretsen, L. & Bahr, R. (2010). Intrinsic risk factors for groin injuries among male soccer players: a prospective cohort study. *The American Journal of Sports Medicine, 38*, 2051-2057.

Escamilla, R., Lewis, C., Bell, D., Bramlet, S., Pecson, A., Imamura, R., Paulos, L. & Andrews, J.R. (2010). Core muscle activation during swiss ball and traditional abdominal exercises. *Journal Of Orthopaedic and Sports Physical Therapy*, 40, 265-276.

Esmaeili, A., Stewart, A., Hopkins, W.G., Elias, G.,Lazarus, B.H., Rowell, A.E & Aughey, R.J. (2018). Normal variability of weekly musculoskeletal screening scores and the influence of training load across an Australian Football League season. *Frontiers in Physiology, 9*, 1-10.

Evans, J.D. (1996). *Straightforward Statistics for the Behavioural Sciences.* Belmont, CA, US: Brooks/Cole Publishing Co.

Faiss, R., Terrier, P., Praz, M., Fuchslocher, J., Gobolet, C. & Deriaz, O. (2010). Influence of initial foot dorsal flexion on vertical jump and running performance. *Journal of Strength & Conditioning Research, 24*, 2352-2357.

Fatouros, I.G. et al. (2011). Validity and reliability of the single-trial line drill test of anaerobic power in basketball players. *Journal Sports Medicine Physical Fitness*, 51, 33-41.

Ferguson, C.J. (2009). An effect size primer: A guide for clinicians and researchers. *Professional Psychology: Research and Practice, 40, 532-538.*

Field, A. (2018). *Discovering Statistics Using IBM SPSS Statistics.* London: Sage.

Flanagan, E.P. & Comyns, T.M. (2008). The use of contact time and the reactive strength index to optimize fast stretch-shortening cycle training. *Strength & Conditioning Journal, 30*, 32-38.

Fong, C.M., Blackburn, J.T., Norcross, M.F., McGrath, M. & Padua, D.A. (2011). Ankle dorsiflexion range of motion and landing biomechanics. *Journal of Athletic Trainer*, 46, 5-10.

Ford, K.R., Myer, G.D. & Hewett, T.E. (2003). Valgus knee motion during landing in high school female and male basketball players. *Medicine and Science in Sports and Exercise*, 35, 1745-1750.

Ford, K.R., Myer, G.D., Smith, R.L., Byrnes, R.N., Dopirak, S.E. & Hewett, T.E. (2005). Use of an overhead goal alters vertical jump performance and biomechanics. *Journal Strength Conditioning Res, 19*, 394-399.

Fort-Vanmeerhaeghe, A., Montalvo, A., Latinjak, A. & Unnithan, V. (2016). Physical characteristics of elite adolscent female basketball players and their relationship to match performance. *Journal of Human Kinetics,* 53, 167-178.

Freckleton, G., Cook, J. & Pizzari, T. (2014). The predictive validity of a single leg bridge test for hamstring injuries in Australian Rules Football Players. *British journal of sports medicine, 48*, 713-717.

Freckleton, G. & Pizzari, T. (2013). Risk factors for hamstring muscle strain injury in sport: a systematic review and meta-analysis. *British journal of sports medicine, 47*, 351-358.

Fritz, J. (2012). Chapter 17: Low Back Rehabilitation. In Andrews, J.R, Harrelson, G.L. & Wilk, K.E. (Eds.), *Physical Rehabilitation of the Injured Athlete 4th Ed* (pp. 333-357). Philadelphia: Elsevier Saunders.

Foster, C., Florhaug, J.A., Franklin, J., Gottschall, L., Hrovatin, L.A., Parker, S., Doleshal, P. & Dodge, C. (2001). A new approach to monitoring exercise training. *Jurnal of Strength and Conditioning,* 15, 109-115.

Fuller, C.W., Ekstrand, J., Junge, A., Andersen, T.E., Bahr, R., Dvorak, J., Hägglund, M., McCrory, P. & Meeuwisse, W.H. (2006). Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. *Scandinavian Journal of Medicine & Science in Sports, 16*, 83-92.

Fuller, C.W., Ojelade, E.O. & Taylor, A. (2007). Preparticipation medical evaluation in professional sport in the UK: theory or practice?, *British Journal Sports Medicine, 41*, 890-6..

Fung, C.M., Blackburn, T., Norcross, M.F., McGrath, M. & Padua, D.A. (2011). Ankle dorsiflexion range of motion and landing mechanics. *Journal of Athletic Training, 46*, 5-10.

Furlanetto, T.S., Sedrez, J.A., Candotti, C.T. & Loss, J.F. (2016). Photogrammetry as a tool for the postural evaluation of the spine: A systematic review. *World Journal of Orthopedics, 7*, 136.

Gajdosik, R.L., Rieck, M.A., Sullivan, D.K. & Wightman, S.E. (1993). Comparison of four clinical tests for assessing hamstring muscle length. *The Journal of Orthopaedic and Sports Physical therapy, 18*, 614.

Gajdosik, R.L. & Bohannon, R.W. (1987). Clinical measurement of range of motion. Review of goniometry emphasizing reliability and validity. *Physical Therapy, 67*, 1867-1872.

Garcia, J., Ibanez, S. J., Gomez, M. A., & Sampaio, J. (2014). Basketball Game-related statistics discriminating ACB league teams according to game location, game outcome and final score differences. *International Journal of Performance Analysis in Sport, 14*, 443–452.

Garcia-Lopez, J., Peleteiro, J., Rodgriguez-Marroyo, J., Morante, J., Herrero, J. & Villa, J. (2005). The validation of a new method that measures contact and flight times during vertical jump. *International Journal of Sports Medicine, 26*, 294-302.

Garcia-Lopez, J., Morante, J.C., Oqueta-Alday, A. & Rodgriguez-Marroyo, J. (2013). The type of mat (contact vs photocell) affects vertical jump height estimated from flight time. *Journal of Strength & Conditioning Research, 27*, 1162-1167.

Goldbeck, T.G. & Davies, G.J. (2000a). Test-retest reliability of the closed kinetic chain upper extremity stability test: a clinical field test. *Journal of Sport Rehabilitation, 9*, 35-45.

Gonzalo-Skok, O., Serna, J., Rhea, M.R. & Marin, P.J. (2015). Relationships between functioanl movement tests and performance tests in young elite male basketball players. *International Journal of Sports Physical Therapy, 10*, 628-638.

Gorman, P.P., Butler, R.J., Plisky, P.J. & Kiesel, K.B. (2012). Upper Quarter Y Balance Test: reliability and performance comparison between genders in active adults. *Journal of Strength and Conditioning Research, 26*, 3043-3048.

Gribble, P.A., Hertel, J. & Plisky, P. (2012). Using the Star Excursion Balance Test to assess dynamic postural-control deficits and outcomes in lower extremity injury: a literature and systematic review. *Journal of Athletic Training, 47*, 339.

Guimarães, E., Ramos, A., Janeira, M/A., Baxter-Jones, A.D.G. and Maia, J. (2019). How does biological maturation and training experience impact the physical and technical performance of 11-14 Year old male basketball players? Sports, 7, 1-13.

Haddad, M., Stylianides, G., Dellal, A. & Chamari, K. (2017). Session-RPE method for training load monitoring: Validity, ecological usefulness, ad influencing factors. *Frontiers in Neuroscience,* 11, 612-615.

Hägglund, M., Walden, M., Magnusson, H., Kristenson, K., Bengtsson, H. & Ekstrand, J. (2013). Injuries affect team performance negatively in professional football: an 11-year follow-up of the UEFA Champions League injury study. *British Journal of Sports Medicine, 47,* 738-742.

Hahs-Vaughn, D.L. (2017). *Applied Multivariate Statistical Concepts* (pp90, 230-232). New York: Routledge.

Haj-Sassi, R., Dardouri, W., Gharbi, Z., Chaouachi, A., Mansour, H., Rabhi, A. & Mahfoudhi, M-E. (2011). Reliability and validity of a new repeated agility test as a measure of anaerobic and explosive power. *Journal of Strength and Conditioning Research*, 25, 472-480.

Hall, E.A & Docherty, C.L. (2017). Validity of outcome measures to evaluate ankle range of motion during the weight-bearing lunge test. *Journal of Science & Medicine in Sport, 20*, 818-621.

Hallet, P. (2010). *A reliability study examining the inter-and intra-observer reliability of the muscle capacity tests included in the ECB musculoskeletal screening protocol* [Masters dissertation]. University of Nottingham, UK.

Hamid, M.A.S., Ali, M.R.M. & Yusof, A. (2013). Interrater and intrarater reliability of the active knee extension (AKE) test among healthy adults. *Journal of PhysicalTtherapy Science,* 25,957-961.

Hammoud, S., Bedi, A., Voos, J.E., Mauro, C.S. & Kelly, B.T. (2014). The recognition and evaluation of patterns of compensatory injry in patents with mechanical hip pain. *Sports Health,* 6, 108-118.

Harmer, P.A. (2005). Basketball injuries. *Medicine Sport Science,* 49, 31-61.

Harrison, A.L., Barry-Greb, T. & Wojtowicz, G. (1996). Clinical measurement of head and shoulder posture variables. *Journal of Orthopaedic & Sports Physical Therapy, 23*, 353-361.

Haryono, I.R., Djajasasana, C.N. & Prastowo, N.A. (2020). The correlation between anthropometric measures, core muscle performance, and running speed in college basketball players. *Acta Kinesiologica*, 14, 5-9.

Hayes, K., Walton, J.R., Szomor, Z.L. & Murrell, G.A. (2001). Reliability of five methods for assessing shoulder range of motion. *Australian Journal of Physiotherapy, 47*, 289-294.

Hegedus, E.J., Goode, A., Campbell, S., Morin, A., Tamaddoni, M., Moorman, C.T. & Cook, C. (2008). Physical examination tests of the shoulder: a systematic review with meta-analysis of individual tests. *British journal of sports medicine, 42*, 80.

Hegedus, E.J., McDonough, S., Bleakley, C., Baxter, D.G., DePew, T.J., Bradbury, I. & Cook, C.E. (2016). Physical performance tests predict injury in National Collegiate Athletic Association athletes: a three-season prospective cohort study. *British Journal of Sports Medicine, 0*, 1-6.

Hegedus, E.J., McDonough, S., Bleakley, C., Cook, C.E. & Baxter, G.D. (2015). Clinician-friendly lower extremity physical performance measures in athletes: a systematic review of measurement properties and correlation with injury, part 1. The tests for knee function including the hop tests. *British journal of sports medicine, 49*, 642-648.

Hegedus, E.J., Goode, A.P., Cook, C.E., Michener, L., Myer, C.A., Myer, D.M. & Wright, A.A. (2012). Which physical examination tests provide clinicians with the most value when examining the shoulder? Update of a systematic review with meta-analysis of individual tests. *British journal of sports medicine, 46*, 964.

Herman, K., Barton, C., Malliaras, P. & Morrisey, D. (2012). The effectiveness of neuromuscular warm-up strategies, that require no additional equipment, for preventing lower limb injuries during sports participation: a systematic review. *BMC Medicine, 10*,1-12.

Herrington, L. (1998). Glenohumeral joint: internal and external rotation range of motion in javelin throwers. *British journal of sports medicine, 32*, 226.

Hertel, J., Miller, S.J. & Denegar, C.R. (2010). Intratester and intertester reliability during the Star Excursion Balance Tests. *Journal of Sport Rehabilitation, 9,* 104-116.

Herzog, M.M., Mack, C.D., Dreyer, N.A., Wikstrom, E.A., Padua, D.A., Kocher, M.S., DiFiori, J.P & Marshal, S.W. (2019). Ankle Sprains in the National Basketball Association, 2013-2014 Through 2016-2017. *The American Journal of Sports Medicine*, 47, 2651-2658. doi:10.1177/0363546519864678

Hetzler, R.K., Stickley, C.D., Lundquist, K.M. & Kimura, I.F. (2008). Reliability and accuracy of handheld stopwatches compared with electronic timing in measuring sprint performance", *Journal of Strength and Conditioning Research, 22*, 1969-1976.

Hewett, T.E., Lindenfeld, T.N., Riccobene, R.V. & Noyes, F.R. (1999). The effect of neuromuscular training on the incidence of knee injury in female athletes: a prospective study. *American Journal Sports Medicine*. *27*, 699–706.

Hewett, T.E., Myer, G.D., Ford, K.R., Paterno, M.V. & Quatman, C.E. (2016). Mechanisms, prediction, and prevention of ACL injurles: cut risk wirtj three sharpened and validated tools. *Journal of Orthopaedic Research*, 34, 1843-1855.

Hibbs, A.E., Thompson, K.G., French, D., Wrigley, A. & Spears, I. (2008). Optimizing performance by improving core stability and core strength. *Sports Medicine, 38*, 995-1008.

Hoare DG. (2000). Predicting success in junior elite basketball players–the contribution of anthropometric and physiological attributes. *Journal Science Medicine Sport, 3*, 391–405.

Hoch, M.C., Staton, G.S. & McKeon, P.O. (2011). Dorsiflexion range of motion significantly influences dynamic balance. *Journal of Science and Medicine in Sport, 14*, 90-92.

Hodgson Phillips, L. (2000). Sports Injury Incidence. *British Journal of Sports Medicine,* 34, 133-136.

Hoffman, J.R., Tenenbaum, G., Maresh, C.M. & Kraemer, WJ. (1996). Relationship Between Athletic Performance Tests and Playing Time in Elite College Basketball Players. *Journal of Strength and Conditioning Research*, 10, 67-71

Hoffman, J.R., Epstein, S., Einbinder, M. & Yitzhak, W. (2000). A comparison between the Wingate Anaerobic Power Test to both vertical jump and line drill tests in basketball players. *Journal of Strength and Conditioning, 14*, 260-264.

Hootman, J.M., Dick, R., Agel, J. (2007). Epidemiology of collegiate injuries for 15 sports: Summary and recommendations for injury prevention initiatives. *Journal of Athletic Training*, 42,311-9.

House of Commons Library. (2018). *The future of basketball in the UK, Debate pack: CDP-2018-0034.* Available at www.parliament.uk/commons-library. (Accessed 16 July 2018).

Hubley-Kozey, C.L. & Vezina, M.J. (2002). Muscle activation during exercises to improve trunk stability in men with low back pain. *Archives Physical Medicine Rehabilitation, 83*, 1100-1108.

Hubscher, M., Zech, A. & Pfeifer, K. (2010). Neuromuscular training for sports injury prevention: a systematic review. *Medicine Science Sports Exercise, 42*, 413-421.

Ibrahim, A. & Murrell, G. (2007). Adductor strain and hip range of movement in male professional soccer players. *Orthopaedic Surgery,* 15, 46-49.

Iunes, D., Bevilaqua-Grossi, D., Oliveira, A., Castro, F. & Salgado, H. (2009). Comparative analysis between visual and computerized photogrammetry postural assessment. *Brazilian Journal of Physical Therapy, 13*, 308-315.

Jenkins, M.T., Gustitus, R., Iosia, M., Kicklighter, T. & Sasaki, Y. (2017). Correlation between the Functional Movement Screen and Hip Mobility in NCAA Division 2 Athletes. *International Journal of Exercsie Science, 10*, 541-549.

Johnston, K., Wattie, N., Schorer, J. & Baker, J. (2017). Talent identification: A systematic review. *Sports Medicine, 48*, 97-109.

Judge, L.W., Moreau, C. & Burke, J.R. (2003). Neural adaptations with sport-specific resistance training in highly skilled athletes. *Journal of Sport Science,* 21, 419-427.

Juker, D., McGill, S., Kropf, P. & Steffen, T. (1998). Quantitative intramuscular myoelectric activity of lumbar portions of psoas and the abdominal wall during a wide variety of tasks. *Medicine and Science in Sports and Exercise, 30*, 301-310.

Keller, R.A., De Giacomo, A.F., Neumann, J.A., Limpisvasti, O. & Tibone, J.E. (2018). Glenohumeral Internal Rotation Deficit and Risk of Upper Extremity Injury in Overhead Athletes: A Meta-Analysis and Systematic Review. *Sports Health*, 10, 125-132.

Koo, T.K. & Li, M.Y. (2016). A guideline of selecting and reporting Intraclass COrrelation Coefficients for reliability research. *Journal of Chiropractic Medicine*, 15, 155-163.

Kibler, W.B., Press, J. & Sciascia, A. (2006). The role of core stability in athletic function. *Sports Medicine, 36*, 189-198.

Kibler, W.B. & Sciascia, A. (2008). Rehabilitation of the athlete's shoulder. *Clinics in Sports Medicine, 27*, 821-831.

Kibler, W.B., Goldberg, C. & Chandler, T.J. (1991). Functional biomechanical deficits in running athletes with plantar fasciitis. *The American Journal of Sports Medicine, 19,* 66-71.

Kiesel, K., Plisky, P.J. & Voight, M.L. (2007). Can Serious Injury in Professional Football be Predicted by a Preseason Functional Movement Screen? *North American Journal Sports Physical Therapy,* 2, 147-158.

Kilinç, F., Yaman, H. & Atay, E. (2009). Investigation of the Effects of Intensive One-Sided and Double-Sided Training Drills on the Postures of Basketball Playing Children. *Journal of Physical Therapy Science, 21*, 23-28.

Kinzey, S.J. & Armstrong, C.W. (1998). The reliability of the star- excursion test in assessing dynamic balance. *The Journal of orthopaedic and sports physical therapy, 27*, 356.

Köklü, Y., Alemdaroglu, U., Ünver Kocak, F., Erol, E.A. & Findikoglu, G. (2011). Comparison of chosen physical fitness chracteristics of Turkish Professional Basketball Players by Division and Playing Position. *Journal of Human kinetics*, 30, 99-106.

Kolber, M.J. & Hanney, W.J. (2012). The reliability and concurrent validity of shoulder mobility measurements using a digital inclinometer and goniometer: A technical report. *The International Journal of Physcial Therapy, 7*, 306-313.

Konor, M.M., Morton, S., Ockerson, J.M., Grindstaff, T.L. (2012). Reliability of three measures of ankle dorsiflexion range of motion. *International Journal Sports Physical Therapy, 7*, 278-289.

Kovacs, I., Tihanyi, J., Devita, P., Racz, L., Barrier, J. & Hortobajyi, T. (1999). Foot placement modifies kinematics and kinetics during drop jumping. *Medicine Science Sport Exercise, 31*, 708-716.

Krause, D.A., Cloud, B.A., Forster, L.A., Schrank, J.A. & Hollman, J.H. (2011). Measurement of ankle dorsiflexion: A comparison of active and passive techniques in multiple positions. *Journal of Sport Rehabilitation, 20*, 333-344.

Kritz, M. 2012, *Development, reliability and effectiveness of the Movement Competency Screen (MCS),* (Doctoral dissertation). Retrieved from https://openrepository.aut.ac.nz/handle/10292/4670 .

Krosshaug, T., Nakamae, A., Boden, B.P., Engebretsen, L., Smith, G., Slauterbeck, J.R., Hewett, T.E. & Bahr, R. (2007). Mechanism of anterior cruciate ligament injury in Basketball: Video analysis of 39 cases. *American Journal of Sports Medicine, 35*, 359-367.

Kuzmitz, F., & Adams, A. (2008). The NFL Conbine: Does it predict performance in the National Football League. *Journal of Strength and Conditioning Research, 22*. 1721-1727.

Lakens, D. (2021). Sample Size Justification. Available at https://doi.org/10.31234/osf.io/9d3yf. Accessed 26th May 2021.

Latin, R.W., Berg, K. &Baechle, T. (1994). Physical and performance chracteristics of NVCAA Division 1 male basketball players. *Journal of Strength and Conditioning Research, 8*, 214-218.

Leanderson, J., Nemeth, G. & Eriksson, E. (1993). Ankle injuries in basketball players. *Knee Surgery Sports Traumatology Arthroscopy, 1,* 200-202.

Leard, J.S., Cirillo, M.A., Katsnelson, E., Kimiatek, D.A., Miller, T.W., Trebincevic, K. & Garbalosa, J.C. (2007). Validity of two alternative systems for measuring vertical jump height. *Journal of Strength and Conditioning Research / National Strength & Conditioning Association, 21*, 1296-1299.

Leetun, D.T., Ireland, M.L., Willson, J.D., Ballantyne, B.T. & Davis, I.M. (2004). Core stability measures as risk factors for lower extremity injury in athletes. *Medicine & Science in Sports & Exercise, 36*, 926-934.

Lehman, G.J. (2005). Resistance training for performance and injury prevention in golf. *Journal Canadian Chiropractic Association, 50*, 27-42.

Leicht, A. S., Gomez, M. A., & Woods, C. T. (2017, August). Explaining match outcome during the men's basketball tournament at the olympic games. *Journal of Sports Science and Medicine, 16*, 468–473.

Linek, P., Sikora, D., Wolny, T. & Saulicz, E. (2017). Reliability and number of trials of Y Balance Test in adolescent athletes. *Musculoskeletal Science & Practice, 31*, 72-75.

Ljungqvist, A., Jenoure, P., Engebretsen, L., Alonso, J.M., Bahr, R., Clough, A., De Bondt, G., Dvorak, J., Maloley, R., Matheson, G., Meeuwisse, W., Meijboom, E., Mountjoy, M., Pelliccia, A., Schwellnus, M., Sprumont, D., Schamasch, P., Gauthier, J.B., Dubi, C., Stupp, H. & Thill, C. (2009). The International Olympic Committee (IOC) Consensus Statement on periodic health evaluation of elite athletes March 2009. *British journal of sports medicine, 43*, 631-643.

Lloyd, R., Oliver, J., Hughes, M. & Williams, C. (2009). Reliability and validity of field- based measures of leg stiffness and reactive strength index in youths. *Journal of Sports Sciences,* 27, 1565-1573.

Lockie, R.G., Callaghan, S.J., Jordan, C.A., Luczo, T.M., Jeffries, M.D., Jalivand, F. & Schultz, A.B. (2015). Certain actions from the Functional

Longo, U.G., Loppini, M., Berton, A., Marinozzi, A., Maffulli, N. & Denaro, V. (2012). The FIFA 11+ program is effective in preventing injuries in elite male basketball players: a cluster randomized controlled trial. *American Journal Sports Medicine*, 40, 996-1005.

Movement Screen do not provide an indication of dynamic stability. *Journal of Human Kinetics, 47*, 19-29.

MacDermid, J.C., Chesworth, B.M., Patterson, S. & Roth, J.H. (1999). Intratester and intertester reliability of goniometric measurement of passive lateral shoulder rotation. *Journal of Hand Therapy, 12*,187-192.

Mackenzie, B. (2005) *Performance evaluation tests*. London: Electric World plc.

Malliaras, P., Cook, J.L. & Kent, P. (2006). Reduced ankle dorsiflexion range may increase the risk of patellar tendon injury among volleyball players. *Journal of Science and Medicine in Sport, 9*, 304-309.

Malliaras, P., Hogan, H., Nawrocki, A., Crossley, K. & Schache, A. (2009). Hip flexibility and strength measures: reliability and association with athletic groin pain. *British Journal of Sports Medicine, 43*, 739-744.

Markovic, G., Dizdar, D., Jukic, I. & Cardinale, M. (2004). Reliability and factorial validity of squat and countermovement jump tests. *Journal of strength and conditioning research / National Strength & Conditioning Association, 18*, 551-555.

Markwick, W.J., Tufano, J.J., Seitz, L.B., Haff, G.G. & Bird, S.P. (2015). The intraday reliability of the reactive strength index calculated from a drop jump in professional men's basketball", *International Journal of Sports Physiology and Performance, 10,* 482-488.

Martuscello, J., Nuzzo, J.L., Ashley, C.D., Campbell, B., Orriola, J.J. & Mayer, J.M. (2013). Systematic review of core muscle activity during physical fitness exercises. *The Journal of Strength and Conditioning Research*, 27, 1684-1698.

Mason-Mackay, A.R., Whatman, C. & Reid, D. (2017). The effect of reduced ankle dorsiflexion on lower extremity mechanics during landing: A systematic review. *Journal of Science and Medicine in Sport*, 20, 451-458.

Mayhew, J.L., Houser, J.J., Briney, B.B., Williams, T.B., Piper, F.C. & Brechue, W.F. (2010). Comparison between hand and electronic timing of 40-yd dash performance in college football players", *Journal of Strength and Conditioning Research, 24*, 447-451.

McCall, A., Carling, C., Davison, M., Nedelec, M., Le Gall, F., Berthoin, S. & Dupont, G. (2015). Injury risk factors, screening tests and preventative strategies: a systematic review of the evidence that underpins the perceptions and practices of 44 football (soccer) teams from various premier leagues. *British Journal of Sports Medicine, 49*, 583-589.

Mcgee, S., & Burkett, L. (2003). The National Football League Combine: A reliable predictor of draft status? *Journal of Strength and Conditioning Research,* 17. 6-11.

McGill, S., Juker, D. & Kropf, P. (1996). Quantitative intramuscular myoelectric activity of quadratus lumborum during a wide variety of tasks. *Clinical Biomechanics, 11*, 170-172.

McGill, S.M., Childs, A. & Liebenson, C. (1999a). Endurance times for low back stabilization exercises: clinical targets for testing and training from a normal database. *Archives of Physical Medicine and Rehabilitation, 80*, 941-944.

McGill, S.M., Grenier, S., Kavcic, N. & Cholewicki, J. (2003,). Coordination of muscle activity to assure stability of the lumbar spine. *Journal of Electromyography and Kinesiology, 13*, 353-359.

McGill, S. (2010). Core training: Evidence translating to better performance and injury prevention. *Strength and Conditioning Journal, 32*, 33-46.

McGill, S., Belore, M., Crosby, I. & Russell, C. (2010). Clinical tools to quantify torso flexion endurance: Normative data from student and firefighter populations. *Occupational Ergonomics, 9*, 55-61.

McGill, S.M., Andersen, J.T. & Horne, A.D. (2012). Predicting performance and injury resilience from movement quality and fitness scores in a basketball team over 2 years. *Journal of Strength and Conditioning Research / National Strength & Conditioning Association, 26*, 1731-1739.

McGuine, T.A., Hetzel, S., Pennuto, A. & Brooks, A. (2013). Basketball Coaches Utilization of Ankle Injury Prevention Strategies. *Sports Health, 5,* 410-416.

McInnes, S., Carlson, J., Jones, C. & McKenna, M. (1995). The physiological load imposed on basketball players during competition. *Journal of Sports Sciences, 13*, 387-397.

McKay, G.D., Goldie, P.A., Payne, W.R. & Oakes, B.W. (2001a). Ankle injuries in basketball: injury rate and risk factors. *British Journal Sports Medicine, 35*,103-108.

McKay, G.D., Goldie, P.A., Payne, W.R., Oakes, B.W. & Watson, L.F. (2001b). A prospective study of injuries in basketball: a total profile and comparison by gender and standard of competition. *Journal Science Medicine Sport, 4*,196-211.

McMahon, J.J, Jones, P.A. & Comfort, P. (2016). A correction equation for jump height measured using the Just Jump System. *International Journal of Sports Physiology & Performance, 11*, 555-557.

McNeil, J.R., Sands, W.A. & Stone, M.H. (2010). Effects of fatigue on kinetic and kinematic variables during a 60 second repeated jumps test. *International Journal of Sports Physiology and Performance, 5*, 218-229.

Meeuwisse, W.H., Sellmer, R. & Hagel, B.E. (2003). Rates and risks of injury during Intercollegiate basketball. *The American Journal of Sports Medicine,* 31, 379-385.

Mehl, J., Diermeier, T., Herbst, E., Imhoff, A.B., Stoffels, T., Zantop, T., Petersen, W. & Achtnich, A. (2018). Evidence-based concepts for prevention of knee and ACL injuries. 2017 guidelines of the ligament committee of the German Knee Society (DKG). *Archives Orthopaedic Trauma Surgery,* 138, 51-61.

Mendez-Villanueva, A., Buchheit, M., Simpson, B., Peltola, E. & Bourdon, P. (2011). Does on-field sprinting performance in young soccer players depend on how fast they can run or how fast they do run? *Journal of Strength and Conditioning Research*, 25, 2634-2638.

Millbank, E.J, Peterson, D.D & Hnery S.M. (2016). The reliability and predictive ability of the Movement Competency Screen in a Military population. *The Sport Journal*.(http://thesportjournal.org/article/the-reliability-and-predictive-ability-of-the-movement-competency-screen-in-a-military-population/).

Miura, K., Yamamoto, M., Tamaki, H. & Zushi, K. (2010). Determinants of the abilities to jump higher and shorten the contact time ina running 1-legged verticak jump in basketball. *Journal of Strength and Conditioning Research*, 24.. 201-206.

Mirwald, R.L., Baxter-Jones, A.D., Bailey, D.A. & Beunen, G.P. (2002). An assessment of maturity from anthropometric measurements. *Medicine & Science in Sports & Exercise*, 34, 689-694

Moir, G., Button, C., Glaister, M. & Stone, M.H. (2004). Influence of familiarization on the reliability of vertical jump and acceleration sprinting performance in physically active men", *Journal of Strength and Conditioning Research, 18*, 276-280.

Mokha, M., Sprague, P.A & Gatens, D.R. (2016). Predicting Musculoskeletal Injury In National Collegiate Athletic Association Division 2 Athletes From Asymmetries and individual-Test Versus Composite Functioanl Movement Screen Scores. *Journal of Athletic Training. 51,* 276-282.

Moran, J.J., Sandercock, G.R., Ramirez-Campillo, R., Meylan, C.M., Collison, J.A. & Parry, D.A. (2017). Age related variation in male youth athletes countermovement jump after plyometric training: A Meta-Analysis of controlled trials". *Journal Strength & Conditioning Research, 31*, 552-565.

Mueller-Wohlfahrt, H. W., Haensel, L., Mithoefer ,K., Ekstrand, J., English B., McNally, S, et al. (2013). Terminology and classification of muscle injuries in sport: the Munich consensus statement. British Journal Sports Medicine, *47*, 342–350.

Mullaney, M.J., Mchugh, M.P., Johnson, C.P. & Tyler, T.F. (2010). Reliability of shoulder range of motion comparing a goniometer to a digital level", *Physiotherapy Theory and Practice, 26*, 327-333.

Munro, A., Herrington, L. & Carolan, M. (2012). Reliability of 2- dimensional video assessment of frontal- plane dynamic knee valgus during common athletic screening tasks. *Journal of Sport Rehabilitation, 21*, 7.

Myer, G.D., Ford, K.R., Barber-Foss, K.D, et al. (2009). The relationship of hamstrings and quadriceps strength to anterior cruciate ligament injury in female athletes. *Clinical Journal Sport Medicine* 19, 3– 8.

Myer, G.D., Ford, K.R., Palumbo, O.P. & Hewett, T.E. (2005). Neuromuscular Training Improves Performance And Lower-Extremity Biomechanics In Female Athletes, *Journal Of Strength And Conditioning Research*, 19, 51-60

Myer, G.D., Ford, K.R. & Hewett, T.E. (2004). Rationale and clinical techniques for anterior cruciate ligament injury prevention among female athletes. *Journal Athletic Training,* 39, 352– 364.

Nadler, S.F., Malanga, G.A., DePrince, M., Stitik, T.P & Feinberg, J.H. (2000). The relationship between lower extremity, low back pain, and hip muscle strength in male and female collegiate athletes. *Clinical Journal Sports Medicine, 10*, 89-97.

Narazaki, K., Berg, K., Stergiou, N. & Chen, B. 2009, "Physiological demands of competitive basketball", *Scandinavian Journal of Medicine & Science in Sports,* vol. 19, no. 3, pp. 425-432.

Natera, A.O., Cardindale, M. & Keogh, J.W.L. (2020). The effect of high volume power training on repeated high-intensity performance and the assessment of repeat power ability: A systematic review. *Sports Medicine,* 50, 1317-1339.

Negrete, R.J., Hanney, W.J., Kolber, M.J., Davies, G.J., Ansley, M.K., McBride, A.B. & Overstreet, A.L. (2010). Reliability, minimal detectable change, and normative values for tests of upper extremity function and power. *Journal of Strength and Conditioning Research, 24*, 3318-3325.

Negrete, R.J., Hanney, W.J., Kolber, M.J., Davies, G.J. & Riemann, B. (2011). Can upper extremity functional tests predict the softball throw for distance: a predictive validity investigation. *International Journal of Sports Physical Therapy, 6*, 104-111.

Nevin, F. & Delahunt, E. (2014). Adductor squeeze test values and hip joint range of motion in Gaelic football athletes with longstanding groin pain. *Journal of Science and Medicine in Sport, 17,* 155-159.

Ness, B.M., Sudhagoni, R.G., Tao, H., Full, O.R., Seehafer, L.O., Walder, C.M. & Zimmey, K. (2018). The reliability of a novel heel-rise test versus goniometry to assess plantarflexion range of motion. *International Journal of Sports Physical Therapy, 13*, 19-27.

Nicholls, A., Leicht, A., Halliday, A. & Doma, K. (2020). Convergent validity and reliability of a novel repeated agility protocol in junior rugby league players. F1000 Research, 9, 624. https://doi.org/10.12688/f1000research.23129.1

Norcross, M.F., Johnson, S.T., Bovbjerg, V.E., Koester, ,.C. & Hoffman, M.A. (2016). Factors influencing high school coaches' adoption of injury prevention programs. *Journal of Science and Medicine in Sport, 19,* 299-304.

Nummela, A., Keränen, T. & Mikkelsson, L. (2007). Factors related to top running speed and economy. *International Journal of Sports Medicine, 28*, 655-661.

Nuzzo, J.L, Anning, J.H. & Scharfenberg, J.M. (2011).The reliability of three devices used for measuring vertical jump height. *Journal of Strength and Conditioning Research, 25*, 2580-90.

Okada, T., Huxel, K.C. & Nesser, T.W. (2011). Relationship between core stability, functional movement, and performance". *Journal Strength Conditioning Research, 25*, 252-261.

Okazaki, V.H.A. & Rodacki, A.L.F. (2012). Increased distance of shooting on basketball jump shot. *Journal of Sports Science and Medicine*, 11, 231-237.

Okazaki, V.H.A., Rodacki, A.L.F. & Satern, M.N. (2015). A review on the basketball jump shot. *Sports Biomechanics*, *14*,190-205

Oliver, J.C.Z., Piatrikova, E., Betts, J.A., Williams, S. & Gonzalez, J.T. (2020). Variability in exercsie physiology: Can capturing *intra*-individual variation help better understand true *inter*-individual responses? *European Journal of Sport Sciences*, 20, 4520460.

Oliver, J.L. & Meyers, R.W. (2009). Reliability and genrality of measures of acceleration, planned agility and reactive agility. *International Journal of Sports Physiology and Performance, 4*, 345-354.

Olmsted, L.C., Carcia, C.R., Hertel, J. & Shultz, S.J. (2002). Efficacy of the Star Excursion Balance Tests in Detecting Reach Deficits in Subjects With Chronic Ankle Instability. *Journal Athletic Training,* 37, 501-506.

Opar, M.D.A., Williams, M.D. & Shield, A.J. (2012). Hamstring strain injuries, *Sports Medicine, 42*, 209-226.

Orchard, J.W. (2001). Intrinsic and extrinsic risk factors for muscle strains in Australian Football. *American Journal of Sports Medicine, 29,* 300-303.

Orchard, J.W. (2015). Men at higher risk of groin injuries in elite team sport: a systematic review. *British Journal of Sports Medicine, 49*, 798-802.

Orchard, J.W., Kountouris, A., Sims, K. (2016). Incidence and prevalence of elite male cricket injuries using updated consensus definitions. Open Access Journal Sports Medicine, 7, 187-94

Ortiz, A., Olson, S.L., Roddey, T.S. & Morales, J. (2005). Reliability of selected physical performance tests in young adult women. *Journal of Strength and Conditioning Research / National Strength & Conditioning Association, 19*, 39-44.

Ostojic, S.M., Mazic, S. & Dickic, N. (2006). Profiling in basketball: physical and physiological characteristics of elite players. *Journal of Strength and Conditioning Research, 20*, 740-744.

Otter, S.J., Agalliu, B., Baer, N., Hales, G., Harvey, K., James, K., Keating, R., Mcconnell, W., Nelson, R., Qureshi, S., Ryan, S., St John, A., Waddington, H., Warren, K. & Wong, D. (2015). The reliability of a smartphone goniometer application compared with a traditional goniometer for measuring first metatarsophalangeal joint dorsiflexion. *Journal of Foot and Ankle Research, 8*, 30.

Papaiakovou, G. (2013). Kinematic and kinetic differences in the execution of vertical jumps between people with good and poor ankle joint dorsiflexion. *Journal of Sport Sciences, 31*, 1789-1796.

Papaiakovou, G,. Fotis, K., Nicodelis, T. & Panoutsakopoulos, V. (2006). Influence of the ankle joint dorsiflexion on the execution of vertical jumps. *Conference: XXIV International Symposium on Biomechanics in Sports,* vol. 1.

Pappas, E., Zazulak, B.T., Yard, E.E. & Hewett, T.E. (2011). The Epidemiology of Pediatric Basketball Injuries Presenting to US Emergency Departments: 2000-2006. *Sports Health, 3,* 331-335.

Parchmann, C.J. & McBride, J.M. (2011). Relationship between functional movement screen and athletic performance. *Journal Strength Conditioning Research, 25,* 3378-3384.

Parkhouse, K.L. & Ball, N. (2011). Influence of dynamic versus static core exercises on performance in field based fitness test. *Journal of Bodywork and Movement Therapies, 15*, 517-524.

Parsonage, J.R., Williams, R.S., Rainer, P., McKeown, I. & Williams, M.D. (2014). Assessment of conditioning-specific movement tasks and physical fitness measures in talent identified under 16-year-old rugby union players. *Journal Strength Conditioning Research, 28*, 1497-1506.

Paul, D, J., Gabbett, T.J. & Nassis, G.P. (2016). Agility in team sports: Testing, Training and Factors Affecting Performance. *Sports Medicine, 46*, 421-442.

Payne, K.A., Berg, K. & Latin, R.W. (1997). Ankle injuries and ankle strength, flexibility and proprioception in college basketball players. *Journal Athletic Training,* 32, 221-225.

Pauole, K., Madole, K., Garhammer, J., Lacourse, M. & Rozenek, R, (2000). Reliability and validity of the T-Test as a measure of agility, leg power and leg speed in college-aged men and women. *Journal of Strength and Conditioning, 14*, 443-450.

Peate, W., Bates, G., Lunda, K., Francis, S. & Bellamy, K. (2007). Core strength: a new model for injury prediction and prevention. *Journal Occupational Medical Toxicology, 2*, 1-9.

Pehar, M., Sekulic, D., Sisic, N., Spasic, M., Uljevic, O., Krolo, A., Milanovic, Z. & Sattler, T. (2017). Evaluation of different jumping tests in defining position-specific and performance-level differences in high level basketball players. *Biology Sport, 34*, 263-272.

Perneger, T. (1998). What's wrong with Bonferroni adjustments. *British Medical Journal,* 316, 1236-1238.

Plisky, P.J., Rauh, M.J., Kaminski, T.W. & Underwood, F.B. (2006). Star Excursion Balance Test as a predictor of lower extremity injury in high school basketball players. *Journal of Orthopaedic & Sports Physical Therapy, 36,* 911-919.

Podlog, L., Buhler, C.F., Pollack, H., Hopkins, P.N. & Burgess, P.R. (2015). Time trends for injuries and illness, and their relation to performance in the National Basketball Association. *Journal Science Medicine Sport, 18,* 278-282.

Podmenik, N., Supej, M., Čoh, M. & Erčulj, F. (2017). The effect of shooting range on the dynamics of limbs angular velocities of the basketball shot. *Kinesiology*, 49, 92-100.

Pollock, N., James, S.L., Lee, J.C. & Chakraverty, R. (2014). British Athletics muscle injury classification: a new grading system. *British Journal of Sports Medicine*, 48, 1347-1351.

Pontillo, M., Spinelli, B.A. & Sennett, B.J. (2014). Prediction of in-season shoulder injury from preseason testing in Division 1 Collegiate football players. *Sports Health, 6,* 497-503.

Powden, C.J., Hoch, J.M. & Hoch, M.C. (2015). Reliability and minimal detectable change of the weight-bearing lunge test: A systematic review. *Manual Therapy, 20*, 524-532.

Power, C.M. (2010). The influence of abnormal hip mechanics on knee injury: A biomechanical perspective. *Journal of Orthopaedic & Sports Physical Therapy, 40*, 42-51.

Prodromos, C.C., Han, Y., Rogowski, J., Joyce, B. & Shi, K. (2007). A meta-analysis of the incidence of anterior cruciate ligament tears as a function of gender, sport, and a knee injury-reduction regimen. *Arthroscopy*, 23, 1320-1325

Puente,C., Abian-Vicen, J., Areces, F., Lopez, R & Del Coso, J. (2017). Physical and physiological demands of experienced male basketball players during a competitive game. *Journal of Strength and Conditioning Research, 31*, 956-962.

Räisänen, A., Pasanen, K. & Parkkari, J. (2014). Relationship between frontal plane knee angle and subjective assessment of knee control during a single leg squat. *British Journal of Sports Medicine, 48,* 653.

Räisänen, A.M., Pasanen, K., Krosshaug, T., Vasankari, T,. Kannus, P., Heinonen, A., Kujala, U.M., Avela, J., Perttunen, J. & Parkkari, J. (2018). Association between frontal plane knee control and lower extremity injuries: a prospective study on young team sport athletes. *BMJ Open Sport & Exercise Medicine, 4*:e000311.

Reid, D.A., Vanweer, R.J., Larmer, P.J., & Kingstone, R. (2015). The inter and intra rater reliability of the netball movement screening tool. *Journal of Science & Medicine in Sport*, *18,* 353-357.

Riddle, D.L., Pulisic, M. & Sparrow, K. (2004). Impact of demographic and impairment-related variables on disability associated with plantar fasciitis. *Foot & ankle international, 25*, 311-317.

Riemann, B.L., Johnson, W., Murphy, T. & Davies, G.J. (2018). A bilateral comparison of the underlying mechanics contributing to the seated single arm shot put functional performance test. *Journal of Athletic Training, 53,* 976-982.

Riva, D., Bianchi, R., Rocca, F. & Mamo, C. (2016). Proprioceptive training and injury prevention in a professional men's basketball team: A six-year prospective study. *Journal of Strength and Conditioning,* 30, 461-475.

Robinson, T.W., Corlette, J., Collins, C.L. & Comstock, R.D. (2014). Shoulder injuries among US high school athletes, 2005/2006-2011/2012. *Pediatrics, 133,* 272-279.

Rodacki, A.L.F., Fowler, N.E. & Bennett, S.J. (2002). Vertical jump coordination: fatigue effects. *Medicine & Science in Sports & Exercise,* 34,105-116.

Ruivo, R., Pezarat-Correia, P., Carita, A. & Vaz, J. (2013). Reliability and validity of angular measures through the software for postural assessment. Postural Assessment Software. *Rehabilitación, 47,* 223-228.

Russell, J.A., Kruse, D.W., Nevill, A.M., Koutedakis, Y. & Wyon, M.A. (2010). Measurement of the extreme ankle range of motion required by female ballet dancers. *Foot & Ankle Specialist, 3*, 324-330.

Sampaio, J., & Janeira, M. (2003, April). Statistical analyses of basketball team performance: Understanding teams' wins and losses according to a different index of ball possessions. *International Journal of Performance Analysis in Sport, 3*, 40–49.

Sampaio, J., Janeira, M., Ibáñez, S. & Lorenzo, A. (2006) Discriminant analysis of game-related statistics between basketball guards, forwards and centres in three professional leagues. *European Journal of Sport Science*, 6, 173-178, DOI: 10.1080/17461390600676200

Sampaio, J., McGarry, T., Calleja-Gonzalez, J., Jimenez Saiz, S., Schelling i del Alcazar, X. & Balciunas, W. (2015). Exploring game performance in the National Basketball Association using player tracking data. *Plos One,* DOI:10.1371/journal.pone.0132894

Sato K, Mokha M. (2009). Does core strength training influence running kinetics, lower-extremity stability, and 5000-M performance in runners? *Journal of Strength Conditioning Research*, 23, 133-140.

Sayers, M.G.L. (2015). Influence of test distance on change of direction speed test results. *Journal of Strength and Conditioning Research, 29,* 2412-2416.

Scanlan, A., Dascombe, B. & Reaburn, P. (2011). A comparison of the activity demands of elite and sub-elite Australian men's basketball competition. *Journal of Sports Sciences, 29*, 1153-1160.

Scanlan, A., Humphries, B., Tucker, P.S. & Dalbo, V. (2014). The influence of physical and cognitive factors on reactive agility performance in men basketball players. *Journal of Sports Sciences, 32*, 367-374.

Schmidtbleicher, D. (1992). Training for power events. *Strength and Power in Sport*, 1, 381-395.

Schneiders, A.G., Davidsson, A., Hörman, E. & Sullivan, S.J. (2011). Functional movement screen normative values in a young, active population. *International Journal Sports Physical Therapy, 6*, 75-82.

Schoenfeld, B.L. (2010). Squatting kinematics and kinetics and their application to exercsie performance. *Journal of Strength and Conditioning Research, 24*, 3947-3506.

Sciascia, A. & Uhl, T. (2015). Reliability of strength and performance testing measures and their ability to differentiate persons with and without shoulder symptoms. *The International Journal of Sports Physical Therapy, 10*, 655-666.

Sekulic, D., Spasic, M., Mircov, D., Cavar, M. & Sattler, T. (2013). Gender-specific influences of balance, speed and power on agility performance. *Journal of Strength and Conditioning Research*, 27, 802-811.

Sekulic, D., Krolo, A., Spasic, M., Uljevic, O. & Peric, M. (2014). The development of a new stop'n'go reactive-agility test. *Journal of Strength and Conditioning Research, 28*, 3306-3312.

Sekulic, D., Uljevic, O., Peric, M., Spasic, M. & Kondric, M. (2017). Reliability and factorial validity of non-specific and tennis specific pre planned agility tests; preliminary analysis. *Journal of Human Kinetics, 30*, 107-116.

Semenick, D. (1990). Tests and measurements: The T-test. *Strength and Conditioning Journal, 12*, 36-37.

Semenick, D. (1990). Tests and measurements: The Line Drill Test. *Strength and Conditioning Journal, 12,* 47-49.

Shackleton, N., Von Randow, M. & Greaves, L. (2019). Methods of sampling in quantitative health research. In Saks, M. & Allspo, J. (Eds). *Researching Health: Qualitative, Quantitative and Mixed Methods* (pp 228-232). London: Sage

Shaffer, S.W., Teyhen, D.S., Lorenson, C.L., Warren, R.L., Koreerat, C.M., Straseske, C.A. & Childs, J.D. (2013). Y- balance test: a reliability study involving multiple raters. *Military medicine, 178*, 1264.

Sharrock, C., Cropper, J., Mostad, J., Johnson, M. & Malone, T. (2011). A pilot study of core stability and athletic performance: is there a relationship? *International Journal of Sports Physical Therapy*, 6, 63–74.

Sheppard, J.M & Young, W.B. (20060. Agility literature review: Classifications, training and testing. *Journal of Sports Science, 24*,.919-932.

Shinkle, J., Nesser, T.W., Demchak, T.J. & McMannus. D.M. (2012). Effect of core strength on the measure of power in the extremities. *Journal of Strength and Conditioning*, 26, 373-380.

Singla, D. & Veqar, Z. (2014). Methods of postural assessment used for sports persons. *Journal of Clinical and Diagnostic Research. 8*, 01-4.

Slinde, F., Suber, C., Suber, L., Edwen, C.E. & Svantesson, U. (2008). The reliability of three different countermovement jump tests. *Journal of Strength and Conditioning Research, 22*, 640-644.

Smith, C.A., Chimera, N.J. & Warren, M. (2015). Association of y balance test reach asymmetry and injury n division 1 athletes. *Medicine & Science in Sports, 47*, 136-141.

Smith, L.J., Creps, J.R., Bean, R., Rodda, R. & Alsalaheen, B. (2017). Performance of high school male athletes on the Functional Movement Screen. *Physical Therapy in Sport, 27*, 17-23.

Spasic, M., Krolo, A., Zenic, N., Delextrat, A. & Sekulic, D. (2015). Reactive Agility Performance in Handball; Development and Evaluation of a Sport-Specific Measurement Protocol. *Journal of sports science & medicine, 14*, 501.

Spiteri, T., Newton, R.U. & Nimphius, S. (2015). Neuromuscular strategies contributing to faster multidirectional agility performance. *Journal of Electromyography and Kinesiology, 25*, 629-636.

Starkey, C. (2000). Injuries and illnesses in the national basketball association: a 10-year perspective. *Journal of Athletic Training, 35*, 161-167.

Stewart, P.F., Turner, A.N. & Miller, S.C. (2019). Reliability, facorial validity, and interrelationships of five commonly used chage of direction speed tests. *Scandinavian Journal of Science Sport,* 24, 500-506.

Stojanovic, E., Stojiljkovic, N., Scanlan, A., Dalbo., Berkelmans, D.M. & Milanovic, Z. (2018). The activity demands and physiological responses encountered during basketball match-play: A systematic review. *Sports Medicine, 48*, 111-135.

Strand, S.L., Hjelm, J., Shoepe, T.C & Fajardo, M.A. (2014). Norms for an isometric muscle endurance test. *Journal of Human Kinetics, 40*, 93-102.

Suchomel, T.J., Sole, C.J., Bailey, C.A., Grazer, J.L. & Beckham, G.K. (2015). A comparison of reactive strength index-modified between six U.S. Collegiate athletic teams. *Journal of Strength and Conditioning Research / National Strength & Conditioning Association, 29*, 1310.

Sullivan, G.M. & Feinn, R. (2012). Using effect size - or Why the *P* Value is not enough. *Journal of Graduate Medical Education, 279-282.*

Suzuki, H., Omor, G., Uematsu, K. & Endo, N. (2015). The influence of hip strength on knee kinematics during a single-legged medial drop landing among competitive collegaite basketball players. *International Journal of Sports Physical Therapy*, 10, 592-601.

Tak, I., Glasgow, P., Langhout, R., Weir, A., Kerkhoffs, G. & Agricola, R. (2016). Hip Range of Motion Is Lower in Professional Soccer Players With Hip and Groin Symptoms or Previous Injuries, Independent of Cam Deformities. *American Journal of Sports Medicine, 44*, 682-688.

Tak, I., Engelaar, L., Gouttebarge, V., Barendrecht, M., Van den Heuvel, S., Kerkoffs, G., Langhout, R,. Stubbe, J. & Weir, A. (2017). Is lower hip range of motion a risk factor for groin pain in athletes? A systematic review with clinical applications. *British Journal of Sports Medicine, 51*, 1611-1621.

Tarara, D.T., Fogaca, L.K., Taylor, J.B. & Hegedus, E.J. (2016). Clinician-friendly physical performance tests in athletes part 3: a systematic review of measurement properties and correlations to injury for tests in the upper extremity. *British Journal of Sports Medicine, 50*, 545-551.

Taylor, J.B., Waxman, J.P., Richter, S.J. & Shultz, S.J. (2015). Evaluation of the effectiveness of anterior cruciate ligament injury prevention programme training components: a systematic review and meta-analysis. *British Journal Sports Med*icine, 49, 79-87.

Taylor, J.B., Wright, A.A., Smoliga, J.M., DePew, J.T. & Hegedus, E.J. (2016). Upper-Extremity Physical-Performance Tests in College Athletes. *Journal of Sport Rehabilitation, 25*, 146-154.

Teo, W., Newton, M.J. & McGuigan, M.R. (2011). Circadian rhythms in exercise performance: implications for hormonal and muscular adaptation. *Journal Sports Science Medicine,* 10, 600-606.

Terada, M., Harkey, M.S., Wells, A.M., Pietrosimone, B.G. & Gribble, P.A. (2014). The influence of ankle dorsiflexion and self- reported patient outcomes on dynamic postural control in participants with chronic ankle instability. *Gait & posture, 40,* 193-197.

Thomas, A., Dawson, B. & Goodman, C. (2006). The Yo-Yo Test: Reliability and association with a 20-m shuttle run and VO_{2max}. *International Journal of Sports Physiology and Performance, 1*, 137-149.

Tong, T.K., Wu, S. & Nie, J. (2014). Sport-specific endurance plank test for evaluation of global core muscle function. *Physical Therapy in Sport, 15*, 58-63.

Torres-Ronda, L., Ric, A., Llabres-Torres, I., de Las Heras, B. & Schelling I Del Alcazar, X. (2016). Position-Dependent Cardiovascular Response and Time-Motion Analysis During Training Drills and Friendly Matches in Elite Male Basketball Players. *Journal of Strength and Conditioning Research / National Strength & Conditioning Association, 30*,. 60-70.

Torres-Unda, J., Zarrazquin, I., Gil, J., Ruiz, F., Irazusta, A., Kortajarena, M., Seco, J.& Irazusta, J. (2013). Anthropometric, physiological and maturational characteristics in selected elite and non-elite male adolescent basketball players. *Journal Sports Science*, *31*, 196–203.

Tran, C.M. & Silverberg, L.R. (2008). Optimal release conditions for the free throw in mens basketball. *Journal of Sports Sciences, 26*, 1147-1155.

Tse, M.A., McManus, A.M & Masters, R.S. (2005). Development and validation of a core endurance intervention program: implications for performance in college-age rowers. *Journal of Strength and Conditioning,* 19, 547-552.

Tucci, H.T., Martins, J., de Carvalho Sposito, G., Camarini, P.M.F. & de Oliveira, A.S. (2014). Closed Kinetic Chain Upper Extremity Stability test (CKCUES test): a reliability study in persons with and without shoulder impingement syndrome. *BMC Musculoskeletal Disorders, 15,* 1.

Valle, X., Alentorn-Geli, E., Tol, J.L., Hamilton, B., Garrett, Jr.w.e., Pruna, R. et al. (2017). Muscle injuries in sports: a new evidence-informed and expert consensus-based classification with clinical application. *Sports Medicine*, *47*, 1241-1253.

van de Pol, R.J., van Trijffel, E. & Lucas, C. (2010). Inter-rater reliability for measurement of passive physiological range of motion of upper extremity joints is better if instruments are used: a systematic review. *Journal of Physiotherapy, 56*, 7-17.

Vanderburgh, P.M. (1998). Two important cautions in the use of allometric scaling: the common exponent and group difference principles. *Measurement in Physical Education and Exercise Science,* 2, 153-163.

Vanderburgh, P.M. & Laubach, L.L. (2008). Body mass bias in a competition of muscle strength and aerobic power. *Journal of Strength and Conditioning Research, 22,* 375-382.

Vanderlei, M.L., Bastos, F.B. de Lemes, I.R. Vanderlei, L.C.M., Junior, N.J. & Pastre, C.M. (2013). Sporting injuries among adolescent basketball players according to position on the court. *International Archives of Medicine*, 6, 1-4.

van Trijffel, E., van de Pol, Rachel J, Oostendorp, R.A. & Lucas, C. (2010). Inter-rater reliability for measurement of passive physiological movements in lower extremity joints is generally low: a systematic review. *Journal of Physiotherapy, 56*, 223-235.

Verrall, G., Slavotinek, J., Barnes, P., Etserman, A., Oakeshott, R. & Spriggins, A. (2007). Hip joint range of motion precedes athletic chronic groin injury. *Journal Science Medicine in Sport,* 10, 463-466.

Vezina, M.J. & Hubley-Kozey, C.L. (2000). Muscle activation in therapeutic exercises to improve trunk stability. *Archives Physical Medicine Rehabilitation, 81*, 1370-1379.

Walbright, D.P., Walbright, N., Ojha, H. & Davenport, T. (2017). Validity of functional screening tests to predict lost-time lower quarter injury in a cohort of female collegiate athletes. *The International Journal of Sports Physical Therapy, 6,* 948-959.

Walsh, M.S., Bohm, H., Butterfield, M.M. & Santhosam, J. (2007). Gender bias in the effects of arms and countermovement on jumping performance. *Journal of Strength and Conditioning Research / National Strength & Conditioning Association, 21*, 362-366.

Wang HK, Chen CH, Shiang TY, Jan MH, Lin KH. (2006). Risk-factor analysis of high school basketball-player ankle injuries: a prospective controlled cohort study evaluating postural sway, ankle strength, and flexibility. *Archives Physical Medical Rehabilitation*, 87(6), 821-5.

Warren, M., Smith, C.A. & Chimera, N.J. (2015). Association of Functional Movement Screen With Injuries in Division I Athletes. *Journal Sport Rehabilitation, 24,* 163-170.

Weiss, K.J., Allen, S.V., McGuigan, M.R. & Whatman C.S. (2017). The relationship between training load and injury in mens professional basketball. International Journal of Sport Physiology and Performance, 12, 1238-1242.

Werner, B.C., Holgrefe, R.E., Griffin, J.W., Lyons, M.L., Cosgrove, C.T., Hart, J.M. & Brockmeier, S.F (2014). Validation of an innovative method of shoulder range-of-motion measurment usinga smartphone clinometer application. *Journal of Shoulder and Elbow Surgery, 23*, 275-282.

Westrick, R.B., Miller, J.M., Carow, S.D. & Gerber, O.J.P. (2012) . Exploration of the Y-balance test for assessment of upper quarter closed kinetic chain performance. *International Journal Sports Physical Therapy, 7*, 139-147.

Whatman, C., Hume, P. & Hing, W. (2013a). The reliability and validity of physiotherapist visual rating of dynamic pelvis and knee alignment in young athletes. *Physical Therapy in Sport, 14*, 168-174.

Whatman, C., Hume, P. A. & Hing, W. (2013b). Kinematics during lower extremity functional screening tests in young athletes are they reliable and valid? *Physical Therapy in Sport*, *14*, 87-93.

Whatman, C., Hing, W. & Hume, P. (2012). Physiotherapist agreement when visually rating movement quality during lower extremity functional screening tests. *Physical Therapy in Sport, 13*, 87-96.

Whiting, J.W., Steele, J.R., McGhee, D.E. & Munro, B.J. (2011). Dorsiflexion capacity affects achilles tendon loading during drop landings. Medicine Science Sports Exercise, 43, 706-713.

Whittaker, J. L., Booysen, N., de la Motte, S., Dennett, L., Lewis, C.L., Wilson, D., McKay, C., Warner, M. & Padua, D. (2016). Predicting sport and occupational lower extremity injury risk through movement quality screening: A systematic review. *British Journal Sports Medicine*, *51,* 580-585.

Whitting, J.W., de Melker Worms, J.L., Maurer, C., Nigg, S.R. & Nigg, B.M. (2013). Measuring lateral shuffle and side cut performance. *Journal of Strength and Conditioning Research / National Strength & Conditioning Association, 27*, 3197-3203.

Wiewelhove, T., Raeder, C., Meyer, T., Kellman, M., Pfieffer, M. & Ferrauti, A. (2015). Markers fir routine assessment of fatigue and recovery in male and female team sport athletes during high intensity interval training. *PLOS ONE*, 1-127. DOI: 10.1371/journal.pone.0139801.

Wilk, K.E., Obma, P., Simpson, C.D., Cain, L.E., Dugas, J. & Andrews, J.R. (2009). Shoulder Injuries n the overhead athlete. *Journal of Orthopaedic & Sports Physical Therapy, 39*, 38-54.

Wilkes, J., Niederer, L., Vogt, L. & Banzer, W. (2018). Head coaches' attitudes towards injury prevention and use of related methods in professional basketball: A survey. *Physical Therapy in Sport,* 32, 133-139.

Willems, T.M., Witrouw, E., Delbaere, K., Mahieu, N., De Bourdeaudhuij, I. & De Clercq, D. (2004). Intrinsic risk factors for inversion ankle sprains in male subjects - A prospective study. *American Journal of Sports Medicine, 33*, 415-423.

Willson, J.D., Ireland, M.L. & Davis, I. (2006). Core strength and lower extremity alignment during single-leg squats. *Medicine Science Sports Exercise*, *38*, 945–952.

Wong, D.P., Chaouchi, A., Della, A. & Smith, A.W. (2012). Comparison of ground reaction forces and contact times between 2 lateral plyometric exercsies in professional soccer players. *International Journal of Sports Medicine*, 33, 647-653.

Jungner, G. & Wilson, J. & World Health Organization (1968). Principles and practice of screening for disease*. Public Health Papers, 34.*

Young, W., Dawson, B. & Henry, G. (2015). Agility and change of direction speed are independent skills: Implications for agility in invasion sports. *International Journal of Sports Science & Coaching, 10*, 159-169.

Young, W.B., Murray, M.P. & Mitch, P. (2017). Reliability of a field test of defending and attacking in Australian football and relationships to reactive strength. *Journal of Strength & Conditioning Research, 31,* 509-516.

Young, W.B., Miller, I.R. & Tapley, S.W. (2015). Physical qualities predict change-of-direction speed but not defensive agility in Australian Rules Football. *Journal of Strength & Conditioning Research, 29,* 206-212.

Young W. (1995). Laboratory strength assessment of athletes. *New Study Athletics, 10*, 88-96.

Zazulak, B.T., Hewett, T.E., Reeves, P.M., Goldberg, B. & Cholewicki, J. (2007). Deficits in neuromuscular control of the trunk predict knee injury risk. *The American Journal of Sport Medicine*, 35, 1123-1130.

Zemková, E. & Hamar, D. (2014). Agility performance in athletes of different sport specializations. *Acta Gymnica, 44*, 133-140.

Zemková, E. & Hamar, D. (2013). Assessment of agility performance under sport-specific conditions. *Asian Journal of Exercise and Sports Science, 10*, 47-60.

Zemkova, E., Vilman, T., Kovacikova, Z. & Hamar, D. (2013). Reaction time in the agility test under simulated competitive and noncompetitive conditions. *Journal of strength and conditioning research, 27*, 3445-3449.

Ziv, G. & Lidor, R. (2009). Physical attributes, physiological characteristics, on-court performances and nutritional strategies of female and male basketball players. *Sports Medicine, 39*, 547-568.

Zuckerman, S.L., Wegner, A.M., Roos, K.G., Djoko, A., Dompier, T.P. & Kerr, Z.Y. (2016). Injuries sustained in National Collegiate Athletic Association men's and women's basketball, 2009/2010-2014/2015. *British Journal of Sports Medicine*, *0,* 1-8.

Appendices.

Appendix 1. Approved ethics application form

ETHICS REVIEW CHECKLIST FOR RESEARCH WITH HUMAN PARTICIPANTS – FACULTY OF SCIENCES

University of Kent

A checklist should be completed for every research project in order to identify whether a full application for ethics approval needs to be submitted. The principal investigator or, where the principal investigator is a student, the supervisor, is responsible for exercising appropriate professional judgement in this review.

This checklist must be completed before potential participants are approached to take part in any research. All forms must be signed by the School's Research Ethics Advisory Group representative.

Section I: Project details		
Project title:	ATHLETE SCREENING AND PERFORMANCE OUTCOMES I BASKETBALL	
Planned start date: 10-09-2016		Planned end date: 30-04-2017
Funder:	SELF FUNDED	

Section II: Applicant details		
Applicant name:	MARK DAYSON	
Department:	SPORT SCIENCES	
Email: mark@daysonphysio.co.uk		Telephone number: 07794711181
Contact address:	1 CHARLES DRIVE, CUXTON, KENT. ME2 1DP.	

Applicant signature	[signature]	**Date**	24/06/2016

Section III: Students only			
Supervisor:			
Undergraduate ☐	Masters ☐	Doctorate ☑	Other (please specify)

Supervisor name	LOUIS PASSFIELD	**Date**	
Supervisor signature			

School REAG rep signature		**Date**	

If any question in Section IV(A) are answered 'yes':
1. **Contact Nicole Palmer** (University Research Ethics & Governance Officer) for advice
2. Send a copy of ethical approval to the Faculties Support Office, once received

If any questions in Section IV(B) are answered 'yes':
1. **Complete full application form**
2. **Send to the Faculties Support Office** for review by the Research Ethics Advisory Group (REAG)

If all questions in Section IV(A) and IV(B) are answered as 'no', **send the completed and signed form to the Faculties Support Office.**

Declaration: Please note that it is your responsibility to follow, and to ensure that, all researchers involved with your project follow accepted ethical practice and appropriate professional ethical guidelines in the conduct of your study. You must take all reasonable steps to protect the dignity, rights, safety and well-being of participants. This includes providing participants with appropriate information sheets, ensuring informed consent and ensuring confidentiality in the storage and use of data.

ETHICS REVIEW CHECKLIST FOR RESEARCH WITH HUMAN PARTICIPANTS – FACULTY OF SCIENCES

University of Kent

Section IV: Research Checklist

Please answer all questions by ticking the appropriate box:

A) Research that may need to be reviewed by an NHS Research Ethics Committee, the Social Care Research Ethics Committee (SCREC) or other external ethics committee (if *yes*, please give brief details as an annex)	**YES**	**NO**
Will the study involve recruitment of patients through the NHS or the use of NHS patient data or samples?	☐	☑
Will the study involve the collection of tissue samples (including blood, saliva, urine, etc.) from participants or the use of existing samples?	☐	☑
Will the study involve participants, or their data, from adult social care, including home care, or residents from a residential or nursing care home?	☐	☑
Will the study involve research participants identified because of their status as relatives or carers of past or present users of these services?	☐	☑
Does the study involve participants aged 16 or over who are unable to give informed consent (e.g. people with learning disabilities or dementia)?	☐	☑
Is the research a social care study funded by the Department of Health?	☐	☑
Is the research a health-related study involving prisoners?	☐	☑
Is the research a clinical investigation of a non-CE Marked medical device, or a medical device which has been modified or is being used outside its CE Mark intended purpose, conducted by or with the support of the manufacturer or another commercial company to provide data for CE marking purposes? (a CE mark signifies compliance with European safety standards)	☐	☑
Is the research a clinical trial of an investigational medicinal product or a medical device?	☐	☑

If the answer to any questions in Section IV(A) is 'yes', please contact the Research Ethics & Governance Officer for further advice and assistance.

B) Research that may need full review by the Sciences REAG	**YES**	**NO**
Does the research involve other vulnerable groups: eg, children; those with cognitive impairment?	☐	☑
Is the research to be conducted in such a way that the relationship between participant and researcher is unequal (eg, a subject may feel under pressure to participate in order to avoid damaging a relationship with the researcher)?	☐	☑
Does the project involve the collection of material that could be considered of a sensitive, personal, biographical, medical, psychological, social or physiological nature.	☑	☐
Will the study require the cooperation of a gatekeeper for initial access to the groups or individuals to be recruited (eg, headmaster at a School; group leader of a self-help group)?	☑	☐
Will it be necessary for participants to take part in the study without their knowledge and consent at the time? (eg, covert observation of people in non-public places?)	☐	☑
Will the study involve discussion of sensitive topics (eg, sexual activity; drug use; criminal activity)?	☐	☑
Are drugs, placebos or other substances (eg, food substances, vitamins) to be administered to the study participants or will the study involve invasive, intrusive or potentially harmful procedures of any kind?	☐	☑
Is pain or more than mild discomfort likely to result from the study?	☐	☑
Could the study induce psychological stress or anxiety or cause harm or negative consequences beyond the risks encountered in normal life?	☐	☑
Will the study involve prolonged or repetitive testing?	☐	☑
Will the research involve administrative or secure data that requires permission from the appropriate authorities before use?	☐	☑
Is there a possibility that the safety of the researcher may be in question (eg, international research; locally employed research assistants)?	☐	☑
Does the research involve participants carrying out any of the research activities	☐	☑

RE V/ARC/DN 26.02.15

ETHICS REVIEW CHECKLIST FOR RESEARCH WITH HUMAN PARTICIPANTS – FACULTY OF SCIENCES

University of Kent

themselves (i.e. acting as researchers as opposed to just being participants)?		
Will the research take place outside the UK?	☐	☑
Will the outcome of the research allow respondents to be identified either directly or indirectly (eg, through aggregating separate data sources gathered from the internet)?	☐	☑
Will research involve the sharing of data or confidential information beyond the initial consent given?	☐	☑
Will financial inducements (other than reasonable expenses and compensation for time) be offered to participants?	☐	☑
Are there any conflicts of interest with the proposed research/research findings? (eg, is the researcher working for the organisation under research or might the research or research findings cause a risk of harm to the participants(s) or the researcher(s) or the institution?)	☐	☑

If the answer to any questions in Section IV(B) is 'yes', please complete the full application form and send to the Faculties Support Office

C) Security Sensitive Material	**YES**	**NO**
Does your research involve access to or use of material covered by the Terrorism Act? (The Terrorism Act (2006) outlaws the dissemination of records, statements and other documents that can be interpreted as promoting and endorsing terrorist acts. By answering 'yes' you are registering your legitimate use of this material with the Research Ethics Advisory Group. In the event of a police investigation, this registration will help you to demonstrate that your use of this material is legitimate and lawful).	☐	☑

Appendix 2. Information sheet for participants (PENDING)

University of Kent

BASELINE AND PHYSICAL PERFORMANCE SCREENING AND THEIR CORRELATIONS TO GAME PERFORMANCE OUTCOMES IN ELITE YOUTH BASKETBALL.

INFORMATION SHEET FOR PARTICIPANTS

Thank you for showing an interest in this project. Please read this information sheet carefully before deciding whether or not to participate. If you decide to participate we thank you. If you decide not to take part there will be no disadvantage to you of any kind and we thank you for considering our request. Participation in this study is on a voluntary basis.

This study has been approved by the School of Sport and Exercise Sciences (SSES) Research Ethics Committee.

What is the aim of the project?

We are interested in examining the relationship between baseline and physical pre-season screening and how they correlate to basketball game performance. Although there is some research to suggest that our performance on the screening does correlate to game performance, we still do not know enough to help us enhance individual player performance. It is hoped that with the knowledge gained from this study, we can begin to design screening interventions to help aid basketball game performance.

What types of participants are needed?

In order for you to be able to participate in this project you need to be 16-19 and free of any chronic illnesses or injury that may prevent you from taking part in this study.

We are looking for individuals who are: enrolled onto the Elite Basketball programme at Canterbury Academy Institute of Sport (CAIS).

What will participants be asked to do?

Should you agree to take part in this project you will be asked to visit the CAIS physiotherapy room on one occasion and the sportshall on two further occasions spread across approximately two-three weeks. You will be asked to comply with certain instructions during this study.

You will not be asked to adjust any element of your daily routine. Additionally, throughout the study you will be asked to maintain your current training program and diet.

The first visit to the physiotherapy room should take approximately 30 minutes. The second and third visits should each take no longer than 60 minutes each. A minimum of 48 hours will be required between visits. The total time investment (excluding travel) is expected to be between 2-4 hours spread across 2-3 weeks.

University of Kent

Can participants change their mind and withdraw from the project?

You may withdraw from participation in the project at any time and without any disadvantage to yourself of any kind. If you decide to withdraw prior to completion of the study, your data will be destroyed and it will not be included in the analysis.

What data or information will be collected and what use will be made of it?

We will be collecting several types of data throughout this study such as physiological (your physical test and heart rate data), and your performance data (game statistics from EABL games). All data will be stored securely on password protected spreadsheets. Your individual results and performance cannot be identified in any of these reports.

Anonymised data may be shared with a research journal to prove that our data is genuine.

What if participants have any questions?
If you would like to receive feedback regarding the results or have any questions about the project, either now or in the future, please feel free to contact:

Researcher Information:

Mark Dayson – mld25@kent.ac.uk

Supervisor Information:

Louis Passfield – l.passfield@kent.ac.uk

Department Information:

School of Sport and Exercise Sciences - +44 (0)1634 888858

Dated: 24/09/2016

University of Kent

During your first visit, we will ask you to sign a consent form and a health questionnaire. We will then take measures of your weight and measure your height. You will then complete a series of passive (movements done for you) and active (movement you do yourself) movement in the physiotherapy room under the guidance of a Chartered Physiotherapist. Measure will be taken of each measure of the shoulder, hip, knee and ankle joint using a tool to measure the angle of movement.

For visit two and three you will be asked to come in and complete a series of physical tests similar to those that are undertaken as part of fitness testing in many sports pre-seasons. The test series will include some upper limb arm strength tests (e.g. chest push), core strength endurance tests (e.g. plank), agility and speed tests (e.g. sprinting), vertical jump tests and an aerobic test (e.g. YoYo test). Each test series will be explained to you in full with clear instructions and guidelines of how to conduct the test and how long it will last.

We will also collate all the game statistics for the academy team across the whole 2016/17 seasons for every EABL game.

Are there any benefits involved in taking part?

We will tell you your testing results and provide information and advice on skills and strategies on improving performance for the tests and we think they may influence in game performance. Additionally, if you wish you can leave your contact details with the researcher, who can provide you with a copy of the overall research findings, which will be written up in a report.

Are there any risks involved in taking part?

During the second and third sessions, you will experience uncomfortable exercise sensations that are typical for high intensity exercise. You are, however, likely to be familiar with these sensations from your own experiences with exercising regularly. During or after these tests, you may experience light-headedness, fainting, discomfort, muscle soreness, nausea and in very rare cases, a cardiac event. These risks, however, are the same during your own regular exercise. For those without underlying heart disease, the risk of a cardiac event is extremely low.

Nevertheless, you will be asked to complete a health questionnaire and we will also measure your resting heartrate and blood pressure, prior to the start to assess your suitability and to further reduce the risk. At all times during the study, you will be closely supervised by a researcher/physiotherapist (who is first aid trained) and a person trained in first aid will always be on site. There is a small chance of picking up an injury (e.g. a muscle pull or strain) and you may also suffer some muscles aches and soreness in the days after testing. These are typical consequences of training. To further reduce the risk of injury, you will have the chance to warm up before the exercise and warm down afterwards too.

Appendix 3. Consent form.

CONSENT FORM

Title of project: Athlete screening and performance outcomes in basketball.

Name of investigator: Mark Dayson

Participant Identification Number for this project:

Please initial box

1. I confirm I have read and understand the information sheet dated… (version…) for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.

2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason. *(Insert contact number here of lead researcher/member of research team, as appropriate).*

3. I understand that my responses will be anonymised before analysis. I give permission for members of the research team to have access to my anonymised responses. *(Also add here a statement about publication of anonymised direct quotes, if this will be done).*

4. I agree to take part in the above research project.

Name of participant	Date	Signature
Name of person taking consent *(if different from lead researcher)* *To be signed and dated in presence of the participant*	Date	Signature
Lead researcher	Date	Signature

Copies:

When completed: 1 for participant; 1 for researcher site file; 1 (original) to be kept in main file

Appendix 4. Qualitative Assessment Single Leg Squat

University of Salford MANCHESTER

ENGLISH INSTITUTE OF SPORT

Qualitative analysis of single leg loading

Date: **Name:**

Condition: **Left** **Right** **Bilateral**

QASLS	Task: Single leg squat Single leg step down Single leg hop for dist	Left	Right
Arm strategy	Excessive arm movement to balance		
Trunk alignment	Leaning in any direction		
Pelvic plane	Loss of horizontal plane		
	Excessive tilt or rotation		
Thigh motion	WB thigh moves into hip adduction		
	NWB thigh not held in neutral		
Knee position	Patella pointing towards 2nd toe (noticeable valgus)		
	Patella pointing past inside of foot (significant valgus)		
Steady stance	Touches down with NWB foot		
	Stance leg wobbles noticeably		
	Total		

Lee Herrington PhD MCSP Knee Research Group University of Salford

Appendix 5. Test Illustrations

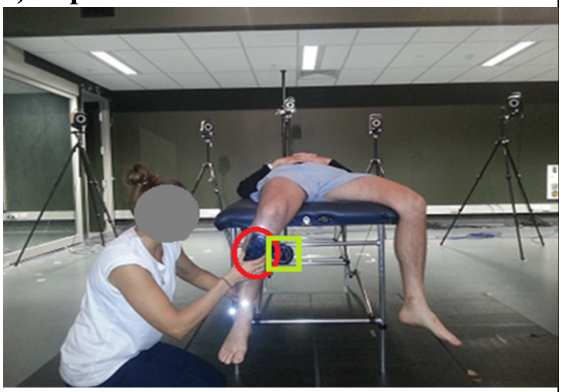
a) Shoulder Internal Rotation

Shoulder internal rotation both passive and active in supine measured using inclinometer.

b) Shoulder Internal Rotation

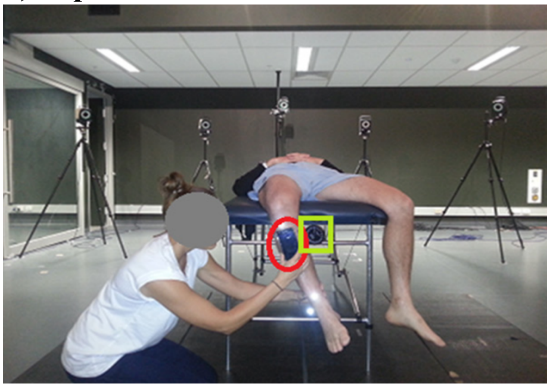
Shoulder external rotation both passive and active in supine measured using inclinometer.

c) Hip Internal Rotation



Hip internal rotation both passive and active in supine measured using inclinometer.

d) Hip External Rotation



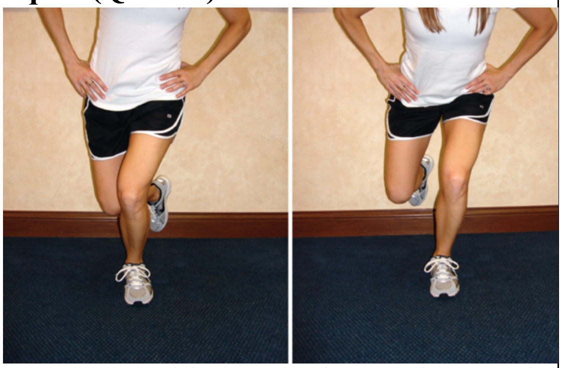
Hip external rotation both passive and active in supine measured using inclinometer.

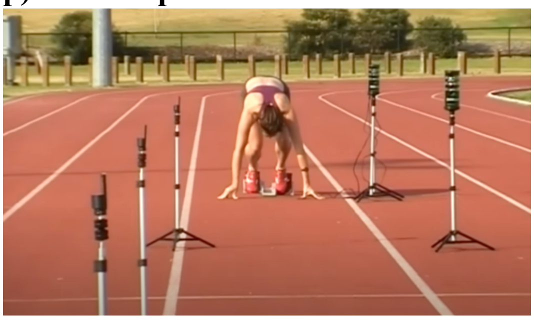
e) Straight Leg Raise

Passive straight leg raise in supine measured using inclinometer.

f) Hamstring 90/90 Test

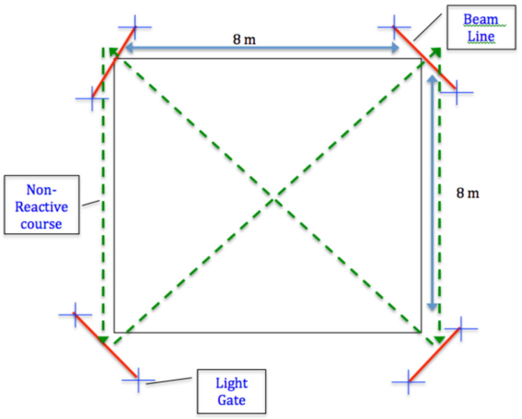
Hamstring length test in supine with hip and knee at 90° measured using inclinometer.

g) Ankle Dorsiflexion  Ankle dorsiflexion in supine measured both passive and active using goniometer.	**h) Ankle Plantarflexion**  Ankle plantarflexion in supine measured both passive and active using goniometer.
i) Adductor Squeeze Test  Adductor squeeze test in supine with hip and knee at 45° in supine measured using biofeedback pressure gauge.	**j) Y Balance Test**  Y Balance test reaching in anterior, posterolateral and posteromedial directions measured using standard tape measures.
k) Qualitative Assessment Single Leg Squat (QASLS)  QASLS considering trunk, arm, knee and foot control.	**l) Countermovement Jump Double**  Countermovement jump with arm swing measured using the Just Jump mat.

m) Counter Movement Jump Single  Countermovement jump single leg with arm swing measured using the Just Jump mat.	**n) Countermovement Jump Double to Backboard**  Countermovement jump with arm swing touching basketball backboard measured using the Just Jump mat. This is repeated jumping to catch a target ball.
o) Counter Movement Jump Single to Backboard  Countermovement jump single leg with arm swing touching basketball backboard measured using the Just Jump mat. This is repeated jumping to catch a target ball.	**p) Linear Speed Tests**  Linear speed sprint tests over 5m, 10, 20m, 30m measured using the Speed Smart system.

<table>
<tr><td></td><td></td></tr>
<tr><td>

q) Reactive and Non-Reactive Agility Test



Reactive and Non-reactive agility testing using the speed Smart system over an 8m square.

</td><td>

r) Sport Specific Endurance Plank

Sport specific plank test alternating between single arm and single leg and opposite arms and leg to failure.

</td></tr>
<tr><td>

s) Side Plank Left & Right

Side plank isometric endurance test left and right to failure.

</td><td>

t) Single Leg Hamstring Bridge Test

Single leg hamstring bridge endurance test repeated to failure.

</td></tr>
<tr><td>

u) Closed Kinetic Chain Upper Extremity Test (CKCUEST)

</td><td>

v) Unilateral Seated Shot Putt

Unilateral seated shot on 45° incline bench measured by standard tape measure for distance.

</td></tr>
</table>

CKCUEST in push up position with tape 36” apart. Maximal touches tape to tape x 3 in 15 secs.	
w) Bilateral Seated Chest Push  Bilateral seated chest push on 45° incline bench measured by standard tape measure for distance.	**x) Ankle Dorsiflexion Lunge Test**  Ankle knee to wall unilateral measured using both inclinometer and standard tape measure.