Read, Paul and Hughes, Jonathan and Stewart, Perry and Chavda, Shyam and Bishop, Chris and Edwards, Mike and Turner, Anthony (2014). ***A Needs Analysis and Field Based Testing Battery for Basketball.*** **Strength and Conditioning Journal, 36 (3), 13-20. ISSN 1524-1602**

Strength and Conditioning Journal

A Needs Analysis and Field Based Testing Battery for Basketball

--Manuscript Draft--

A Needs Analysis and Field Based Testing Battery for Basketball

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Abstract

Basketball is a high intensity sport requiring a range of athletic abilities; explosive strength and rate of force development, agility, co-ordination, speed, anaerobic lactate and alactic capacities. Within elite basketball strength and conditioning programmes, distinct variation in the assessment of such qualities is evident, highlighting the need for evidence based practice to determine acceptable validity and reliability of the measures used. Therefore, the purpose of this review was to determine the physiological requirements of the sport so that suitable testing approaches can be identified from which coaches can optimally assess the physical capabilities of their athletes.

Key Words: Basketball, Testing, Physical Performance

Introduction

Basketball involves repeated bouts of intense action such as, sprinting, abrupt stops, fast changes in direction, acceleration, shuffling and jumping separated by short bouts of low intensity activity in the forms of walking, jogging and recovery (Abdelkrim et al., 2007). For high levels of performance in the above tasks it has been suggested that players must possess the following motor and functional abilities; explosive strength and rate of force development (RFD) in the legs, strength of the arms and shoulder girdle, agility with and without the ball, co-ordination, speed, anaerobic lactate and alactic capacities (Stone, 2007). This is supported by Erculj et al. (2003) identifying that explosive strength, RFD, speed and agility contributed significantly ($p < 0.05$) to efficient movement with and without the ball. Thus, it can be determined that physical qualities play an important role in the requisite performance of basketball techniques.

Successful basketball performance is also influenced heavily by anthropometrics (e.g. limb length, stature and mass), with elite players being greater in stature (Hoare, 2000). However, evidence suggests that taller players are inferior in their general motor abilities (Kapowicz, 2006), including; acceleration and acyclic speed both with and without the ball (Erculji et al., 2003). As such, the development of athletic qualities for basketball athletes is paramount to performance and should be considered a fundamental component of a holistic training program.

Distinct variation is evident in the physical and physiological assessment methods of a range of fitness components (strength, speed, power, endurance, agility, flexibility and body composition) in elite basketball. This was highlighted by Simenz et al. (2005) in their analysis of the practices undertaken by strength & conditioning (S&C) coaches within the national basketball association (NBA). Such variety prevents the establishment of normative data from which practioners can compare basketball athletes to national standards. Additionally, the validity and reliability of the selected assessment methods may be affected. The purpose of this review was to analyze the physiological requirements and injury considerations of the sport in order to identify suitable testing approaches from which coaches can optimally assess the physical capabilities of their athletes.

Time Motion Analysis

Time motion analysis is a key tool for determining fundamental movements of play and the frequency in which they occur. In match play, nine specific movements have been identified, including; standing, walking, jogging, running, striding, sprinting, jumping, turning and side movements (Abdelkrim et al., 2007), with thirty four percent of the game in active movements, such as, running and jumping (Nazaraki et al., 2008). To allow the reader to fully understand the physiological demands of the sport, in this review, high intensity activities will be defined in accordance with the work of Abdelkrim et al. (2007) to include; sprinting, abrupt stops, fast changes in direction, acceleration, shuffling and jumping.

Highlighting the multi-directional nature of the sport, reported changes between movement patterns occur every two seconds (McInnes et al., 1995). This would imply that frequent changes of direction, and subsequently speed and agility are of major importance in match play. Further, it was evidenced that 22% of the game distances covered involved lateral movement. This is an important consideration for strength & conditioning specialists due to the fact that lateral movements have been reported to be more metabolically demanding in comparison to straight line running (Ziv and Lidor, 2009). Therefore, the development of strength, optimal mechanics and conditioning in multiple planes of movement (frontal, saggital and transverse) should be considered essential.

Initial research pertaining to game analysis has identified differential demands based on position, namely; guards, forwards and centres. Positions are then further defined by specific roles; centres, point guard, shooting guard, small forward and power forward. Centres are involved in less high intensity movements than both forwards and guards respectively (Grosgeorge, 1990), with forwards completing greater volumes of running (Miller and Bartlett, 1994). More recently, the frequency of high intensity movements during a game has also been analyzed, with Abdelkrim et al. (2007) reporting higher occurrences in guards and forwards compared with centres (17.1%, 16.6% vs 14.7%) respectively. It is also important to note, that this research has been carried out since the rule change in May 2000. These modifications have resulted in shorter attack times from 30 to 24 seconds, a reduction in the time spent on the backcourt and 4 ten minute quarters as opposed to two 20 minute half's. This adjustment also precipitated an alteration in the game demands leading to the increased time spent in high intensity activities (Abdelkrim et al., 2007). As such, caution is required when referring to evidence in the literature as it may not be truly reflective of current game demands, including the work of Miller and Bartlett (1994) where high intensity movements were performed every 21 seconds and only 5% of sprints lasted more than 4 seconds. Although the above data could be deemed useful in designing assessment and conditioning strategies based on positional differences with an optimization of work to rest ratios, it may not be truly reflective of current game demands. Therefore, the work of Abdelkrim et al. (2007) may provide a more accurate representation. However, practioners should also be cognizant of the fact that the subjects used in the work of Abdelkrim et al. were elite U19 players, and as such, these results may not be applicable to players of all ages and levels.

To date, limited evidence is available regarding distances covered during a game. Abdelkrim (2010) reported that a total of 7,558 metres provided a baseline figure during junior basketball matches, with only 2% of match play involving high intensity activities. Although this data may be valid for junior players, its relevance to adult and elite populations is speculative. Further to this, it should be noted that it is not the total distance covered that dictates basketball performance (Abdelkrim, 2010). Therefore, it has been suggested that determining the amount of high intensity activity may be a more prudent strategy to differentiate between levels of performance (Abdelkrim, 2010).

Physical requirements of the Game

For successful performance, players are required to possess a number of physical attributes, including; muscular power (Hunter, Hilyer and Foster, 1993), aerobic power (Hunter et al., 1993), speed and agility (Hoffman et al., 1991). The relationship between athletic ability and playing time has been measured previously (Hoffman et al., 1996), with players demonstrating the greatest athletic ability (based on the fitness tests) accumulating greater playing times. As such, determining the level of appropriate physical qualities is of fundamental importance for strength & conditioning coaches for talent identification and monitoring the effects of their programming.

Energy System Requirements

It has been suggested that a large proportion of the energy required for the high intensity bursts within a game is derived from the Adenosine Tri-Phosphate (ATP) and Creatine Phosphate (CP) systems (Baslom et al., 1992). Abdelkrim et al. (2010) identified, 6 seconds of high to moderate intensities followed by 22 seconds of sub maximal work (walking, jogging and recovery) equating to a mean work to rest ratio of 1:3.6. This suggests an insufficient time period in which to replenish creatine phosphate stores, and a subsequent reliance on anaerobic glycolysis (Baslom et al., 1992). Additionally, Ratamass et al. (2008) identified that the metabolic demands of basketball required a high proportion of the phosphagen system, a moderate to high requirement for anaerobic glycolysis, and the contribution of aerobic metabolism as a less significant factor. Collectively these findings demonstrate the need for the inclusion of appropriate testing and training protocols for both the anaerobic alactic (underpinned by the ATP-PC systems) and anaerobic glycolytic systems (Castagna et al., 2008), i.e. maximal sprint tests and repeated sprint protocols.

Aerobic vs. Anaerobic

Speculation as to whether Basketball should be classified as an aerobic or anaerobic sport is present within the available literature. A reliance on the ATP-PC and glycolytic systems has been suggested (Hoffman et al., 1991), with the aerobic system identified as a secondary energy source. This is highlighted in the fact that mean $V0_{2max}$ values are lower than that of other more endurance based activities (Caterisano et al., 1997). Further support can be derived from Hoffman et al. (1996) who suggested that basketball appears to be more dependent upon anaerobic power, rather than aerobic power and capacity. Over a four year period assessing the relationships between athletic performances and playing time, a significant negative correlation was reported with aerobic capacity. Of particular note, when aerobic fitness was greater than or equal to the population average, no further benefit was derived when aerobic fitness was greater than or equal to the population average, no further benefit was derived. This suggests that once an aerobic base has been established sport specific practices and games may be sufficient to maintain aerobic fitness. This is especially important for strength and conditioning coaches to consider, as it has been reported that continuous aerobic training in anaerobic sports leads to mal-adaptations and performance decrements, for example reductions in strength, power (Elliot et al., 2007) and rate of force development (Behm and Sale, 1993).

The intensity demands are also reflected by the fact that lactate production is evident in basketball. McInnes et al. (1995) reported elevated blood lactate levels throughout a basketball game, with a high variability among players. This is supported by Abdelkrim et al. (2007) who reported that mean (SD) plasma lactate concentrations [La] were significantly higher for guards ($p<0.05$) than for centres (6.36 (1.24) v 4.92 (1.18) mmol/l, respectively. It was suggested that the elevated lactate levels demonstrate a glycolytic pathway making an important contribution to energy production during a game. As well as the reported lactate production, heart rate has also been analysed during competition (Abdelkrim et al., 2010), where it was shown that heart rate was above 95% for 19% and above 85% for 74% of game play.

Contrary to the above evidence, aerobic endurance has been reported to affect basketball performance (Abdelkrim et al., 2007). Specifically, distance covered in a maximal shuttle-running test was related to basketball game variables, namely the ability to sustain high-intensity efforts (Abdelkrim et al., 2007; Castagna et al., 2008). Of note, Castagna et al. (2008) assessed aerobic performance using the Yo-Yo IR1 detecting significant differences across the competitive level ages, demonstrating the construct validity of the Yo-Yo IR1 within basketball. This is in contradiction to the work of Hoffman (1996) as stated above, however, a growing body of research has highlighted the importance of aerobic performance. For example, Abdelkrim et al. (2010) determined that aerobic performance (in the form of a 20 metre repeated shuttle test) was associated with high intensity performance during a basketball game. In spite of this, it should be considered that this test, due to the non-continuous nature, deceleration, changes of direction and acceleration components is not a true test of aerobic performance, rather a test of repeated incremental shuttles demonstrating both aerobic and anaerobic requirements.

Accordingly, it should be considered based on the literature outlined above, that successful basketball performance is underpinned by maximal anaerobic parameters (i.e. maximal sprints and jumps), the ability to repeat high intensity movements under conditions of fatigue (namely repeated sprint ability), and periods of low level activity involving recovery via aerobic metabolism. Based on this, strength and conditioning coaches may wish to consider a primary emphasis of testing and training protocols for both maximal acceleration and repeated sprint abilities with aerobic abilities as a secondary measure.

Strength and Power

Strength is a key component within elite basketball, highlighted by Delextrat and Cohen (2008) in their assessment of knee extensor strength using an isokinetic dynamometer, noting that first team players developed significantly greater peak torques than second team players. Therefore, elite players may be stronger than lesser skilled players. However, it should be considered that the assessment used in their work requires expensive equipment and may not reflect closed chain movement patterns inherent to basketball, such as jumping and sprinting. Of note, 1 repetition maximum (1RM) squat strength has demonstrated strong correlations ($r = 0.94$) with increases in vertical jump height and improved acceleration abilities in elite level soccer players (Wisloff et al., 2004). Therefore, it could be argued that the 1RM squat test is a valid measure of strength in the assessment of elite basketball performance. This becomes more apparent with Hoffman (1991) reporting that squat strength should be considered as a staple performance variable throughout a competitive season and is also a good predictor of playing time. Additionally, 1RM squat strength has been shown to be the best single predictor of 5 and 10m sprint times in elite basketball players (Chaouachi et al., 2009), with the ability to squat 1.5 times bodyweight a suggested strength pre-requisite for elite level males (Hoffman et al., 1996).

The ability to generate maximal force in the shortest period of time has been considered essential in achieving high levels of basketball performance (Brittenham, 1996), with elite players characterised by a significantly higher percentage of fast twitch fibers than less skilled competitors (Sergej, Ostojic and Nenad, 2006; Bolonchuk et al., 1991). In support of this, Latin et al. (1994) measured the physical abilities of elite collegiate players, identifying that high levels of strength and anaerobic parameters enable more powerful rebounds, in addition to enhanced shooting, shuffling and jumping performances. With vertical jump scores ranging from 60cm (Vitasalo et al., 1992) to mean values of more than 70cm (Hoffman et al., 1996), it is suggested that elite players achieve significantly greater vertical jump heights. Confirming this, Hoare. (2000) reported significant differences in jump height between the 8 best shooting guards and the other shooting guards involved in a national championship. In addition, the ability to repeat this explosive action across the course of a game is also of great importance, with reports of 44-46 jumps during a game (Abdelkrim et al., 2007; McInnes, 1995). Consequently, jumping is a key determinant to basketball performance and should form part of athlete assessment strategies.

Upper body strength in the form of 1RM bench press has also been assessed with first team players displaying greater strength scores, compared with those of the second team (Delextrat and Cohen, 2008). This has been confirmed by Caterisano et al. (1997) who reported a difference of 6.3% between the 'best' and the 'rest' of players with collegiate level athletes. These findings suggest that an appropriate level of upper body strength is necessary for optimal basketball performance. However, the primary emphasis should remain with multi-joint lifts such as squats, deadlifts and Olympic lifting variations, as confirmed by Hoffman et al. (1996) where 1RM bench press scores were not a good indicator of playing time.

Agility

Agility has been suggested as a key physical component in a number of team sports, including basketball (Delextrat and Cohen, 2009). Due to frequent changes of direction and reactive nature of the sport (McInnes, 1995), agility has been established as a physiological pre-requisite for successful performance (Hoffman et al., 2000). Traditionally defined as the ability to change direction rapidly, without losing balance, using a combination of strength, power and neuromuscular co-ordination (Little and Williams, 2005). Such qualities are clearly evident within game play however; this may be more accurately described as change of direction speed (Young et al., 2002). More recently, Shephard and Young. (2006) have identified that agility is affected by the athlete's perception and decision making skills. This is highlighted by the fact that more skilled athletes are better able to respond to kinematic and postural cues (Abernethy et al., 1998).

When considering appropriate change of direction speed or agility tests for basketball it should be considered that players are not only required to sprint in linear planes of motion. Backwards gait and side shuffling movements are common, subsequently suggesting the relevance of the T-Test. This is supported by Delextrat and Cohen. (2008) where first team players achieved significantly lower times compared to the second team, further confirmed by Gillam (1985), with significant differences between basketball athletes and physical education majors. Whilst, the T-Test has gained support within the literature, other change of direction speed tests including the pro-agility test or 5-0-5 may also be appropriate due to the frequent changes of direction (McInnes, 1995) and inherent game demands where sprints will often begin whilst players are in motion (Abdelkrim, 2007), further justifying the use of the 5-0-5 test. Also speculatively, performing lateral motions in closed environments under timed conditions (as in the T-Test) is not reflective of the perceptual components and will likely effect movement mechanics, thus reducing the content validity of the test. An alternative option may be to perform a qualitative assessment of lateral abilities and changes of direction in response to a variety of stimuli. Lastly it should also be noted at this point that none of the tests suggested above are true tests of agility, however, at this time efficient, cost effective and reliable measures are limited (Turner, 2012).

Speed

When analysing speed, the majority of the literature has reported data pertaining to distances of 20-27 metres, close to length of the basketball court (Hoffman et al., 2000).

It should be considered that players rarely cover these distances in the same high intensity effort with average distances of 10m recorded or between 1.7 and 2.1 seconds in duration (Abdelkrim et al., 2007; McInnes, 1995). Therefore, the use of shorter distance tests (5 and 10m) to assess linear speed may be a more prudent strategy, with the measurement of maximal running speed considered inappropriate. With the requirement for quick accelerations and decelerations this further advocates the importance of strength, due to the ability and effort required to overcome the body's inertia (McInnes et al., 1995). It was also noted by Abdelkrim et al. (2007) that the percentage of high intensity movements was reduced in each quarter. As such, the ability to repeat sprints under conditions of fatigue (i.e. the 12x20m repeated sprint test) may be deemed appropriate.

An assessment and training method that is commonly used within basketball is the suicide run. Hoare (2000) reported significant differences in suicide run time in the 'best' versus the 'rest' in their assessment of Australian male and female basketball players. However, the use of suicide runs has been questioned (Delextrat and Cohen, 2008), due to their non-specific nature in terms of game demands. An-aerobic capacity, a key component of successful basketball performance, defined as the maximal rate of energy production by the combined phosphagen and lactic acid energy systems, has been suggested as the primary component for exercises lasting 30-90 seconds (Maud and Fosters, 2006). Whilst it has been proposed that this test may reflect the anaerobic capacity component of competition (Maud and Foster, 2006), with a duration of approximately 30 seconds, validity concerns within the literature are present. This was highlighted by Delextrat and Cohen. (2008) who reported no significant differences between first and second team players in suicide run performance. This likely due to the shorter, higher frequency game actions as has been reported previously (Abdelkrim, 2007).

Aerobic Capacity

As mentioned above aerobic performance has been shown to affect the game of basketball due to the ability to repeat high intensity efforts (Castagna et al., 2005; Abdelkrim et al., 2007). According to Castagna et al. (2005), the YYIR1 was able to detect significant differences across competitive levels, suggesting that basketball requires well developed aerobic and anaerobic capabilities, as has been confirmed elsewhere (Abdelkrim et al., 2007: Miller, 1994; Abdelkrim et al., 2010). Whilst this evidence should be considered, further research may be necessary to support these findings as it opposes the majority of previous research discussed above.

Landing Mechanics / Utilization of the Stretch Shortening Cycle (SSC)

It has been evidenced that maximal power production in jumping tasks is related to lower limb stiffness (Arampatzis et al., 2001). Further that athletes from power based sports demonstrating higher leg stiffness than endurance-trained athletes during a one-legged vertical jump (Laffaye et al., 2005). Stiffness is an important parameter to the power athlete as they will maximise the storage and release of elastic energy in the musculotendinous unit to improve muscle power and jump height (Bobbert, 2001). During a counter-movement jump, a stiffer musculotendinous system might benefit the performance via a faster elastic recoil during the upward, concentric, phase of the jump

(Arampatzis et al., 2001), as well as a more efficient transfer of force to the skeleton (Wilson et al., 2003). Rabita et al. (2008) speculated that in trained athletes with a skilled motor programme, the neuromuscular system adopts strategies to find the optimal balance between these conflicting requirements.

In-effective absorption of impact forces has been noted within basketball (Erculj, Mateja and Bracic, 2010). In particular, it was highlighted that females demonstrated inadequate abilities to with-stand eccentric forces upon landing. This is an important consideration for strength and conditioning coaches due to increases in injury risk, in addition to an in-ability to effectively utilize elastic energy accumulated in the eccentric phase of the jump (Bobbert et al., 1996). It has been suggested that the longer ground contact times displayed within basketball athletes may be due to player specific body constitution, differences in jumping technique, poorly developed explosive strength and elasticity of the leg extensor muscles due to insufficient rigidity and poor landing mechanics (Ecrulj et al., 2004). Subsequently, an assessment of the athlete's limb stiffness and reactive strength index (RSI) is recommended as a measure of their effectiveness in switching from an eccentric to a concentric contraction. In addition, a qualitative assessment of landing mechanics, such as the Landing Error Scoring System (L.E.S.S), established by Padua et al. (2009) will provide coaches with useful information that may aid in injury prevention.

Uni-Lateral Assessment / Asymmetry

Another consideration in the assessment of basketball players is preferred limb dominance and muscle balance. Theoharopoulos and Tsitskaris (2000) noted a difference in the ankle plantar-flexor strength in favour of the preferred take off limb in professional basketball players with observed differences of 10%. Some element of limb asymmetry is to be anticipated, however, these findings may validate the use of a single leg countermovement jump (CMJ) to determine power ratios and imbalances between limbs. Of note; Bracic et al. (2010) identified that elite sprinters who demonstrated lower bi-lateral deficits in CMJ, produced higher peak forces (r = 0.63). This is an important consideration, as in addition to performance decrements, it has been reported that a discrepancy >15% is an important injury predictor (Crossier and Creeland, 2002). Subsequently the inclusion of a uni-lateral measure of performance, such as a single leg CMJ is recommended.

Fitness Tests

As highlighted above, strength, power, agility and speed are important characteristics for elite basketball players (Hoffman et al., 1991; Latin et al., 1994). Based on the evidence outlined in this article, the following testing battery is proposed to assist strength and conditioning coaches in the determination of the physical abilities of basketball players (see table 1). It is suggested that the order of testing provided is the most appropriate (i.e. least to most fatiguing), and will ensure optimal efficiency. Further, the specified sequencing is in agreement with NSCA recommendations (Harman, 2008).

****************************Table 1 near here******************************

Injuries in basketball

Previous work has reported that male high school basketball players sustained injuries at a rate of 16.9 per 1000 hours of game exposure (Messina et al., 1999). By way of comparison, the National Basketball Association noted an overall game injury rate of 19.3 per 1000 athlete exposures (Deitch et al., 2006). This data suggests that injuries are prevalent within competition, in particular, the joints most at risk are the knee (19.1%), ankle (16.9%), lumbosacral spine (9%) and the foot, accounting for 7.9% (Deitch et al., 2006). Additionally, 37% of all injuries occurred in the upper extremity with finger and shoulder the most frequent sites (Kostopoulos and Dimitrios, 2010).

Conversely, Randall et al. (2007) reported that the highest proportion of injuries were ankle ligament sprains (26.2%), with knee internal derangements as secondary (7.4%), over a 16 year period in male collegiate basketball players. Consequently, an important consideration for the S&C coach is to provide a detailed assessment of static and dynamic unilateral stability due to reported inhibition of the gluteus maximus and gluteus medius (key hip extensors and hip abductors respectively) following the occurrence of an ankle injury (Bullock Saxton et al., 1994; Friel et al., 2006). Such neuromuscular deficiencies may result in greater frontal plane loads at the knee, coinciding with higher hip adduction moments due to reduced muscle activation during landing tasks (Hewett et al., 2005). This bears relevance as ACL injuries likely occur when active muscular restraints are unable to compensate and adequately reduce joint torques during dynamic movements, such as landing, decelerating and pivoting (Beynnon and Flemming, 1998). Consequently, reduced neuromuscular control directs excessive stress to the passive ligamentous structures which may exceed their strength limit, resulting in mechanical failure (Li et al., 1999).

The primary injury mechanisms within a game have been classified as player contact, other contact (e.g. balls or the ground) and no contact, with the highest proportion of injuries being as a result of player contact (Randall et al., 2007). In the same study the authors determined that a majority of the injuries were soft tissue in nature, to the lower limb and back, attributed to the fact that basketball is characterized by rapid changes of direction, non linear movements and high eccentric forces (in the forms of landing from a jump, cutting manoeuvres and sudden decelerations). A point of caution is highlighted by Beiser et al. (2001) in their analysis of planned vs. unplanned cutting movements. In the subjects tested, unplanned cutting tasks allowed insufficient time to make the necessary postural adjustments, resulting in compromised leg placements and significantly greater loads on the knee joint. The authors summarised that learning to respond to stimuli more quickly in change of direction tasks may enhance performance and also reduce injury risk. This suggests that the development of sufficient strength and neuromuscular control is essential in order to tolerate the increased forces displayed in open environments. In addition, it is recommended that players develop optimal on court movement mechanics using primarily closed drills, and when technique is appropriate, progress to more open situations with a reactive component. It is beyond the scope of this article to discuss further details of approaches to develop change of direction speed and agility, however, the reader is directed to the work of Turner et al. (2011) and for specifics to youth populations, Lloyd et al. (2013) for more detailed explanations.

Summary

This article has provided an analysis of the demands of basketball with regards to the key physical, physiological and biomechanical components. Further, based on the evidence provided, a subsequent testing battery has been proposed by which strength and conditioning professionals can effectively assess and monitor the abilities of their athletes to assist in the development of optimal training provision with the aims of reducing injuries and optimising performance.

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Table 1: Suggested Fitness Testing Battery for the assessment of the physical abilities of Basketball players.

Physical Characteristic	**Test**	**Rest Period**
Gym Tests		
Anthropometry	3 Site Skinfold, Height, Weight	n/a
Flexibility	Overhead Squat in addition to Goniometric assessment of ankle dorsiflexion, hip extension, internal / external rotation and shoulder flexion	n/a
Power	Squat Jump, Countermovement Jump	≥ 5 mins
Asymmetry	Single Leg Countermovement Jump	
Stiffness, RSI and Landing Mechanics	Submaximal hopping, Drop Jump (30cm box) and Landing Error Scoring System (L.E.S.S) Test	
Strength	1 Repetition Maximum Squat, Bench Press (if technique is appropriate)	
Court Based Tests		
Agility	T-Test and Pro Agility	≥ 5 mins
Acceleration	10m Sprint	
Anaerobic Capacity	Short Repeated Sprint Test (12x20m)	n/a