Competition-specific development and preparation of elite basketball athletes

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The following studies involved human subjects and received approval from the Ethics committees:

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Ethics approval number 2011/013 by Human Research Ethics Committee of Charles Sturt University 25th January 2011.
Certificate of authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma at Charles Sturt University or any other educational institution, except where due acknowledgment is made in the thesis. Any contribution made to the research by colleagues with whom I have worked at Charles Sturt University or elsewhere during my candidature is fully acknowledged. I agree that this thesis be accessible for the purpose of study and research in accordance with the normal conditions established by the Executive Director, Library Services or nominee, for the care, loan and reproduction of theses.

Date:

Candidate’s signature:
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Abstract

Developing elite basketball athletes is dependent on a competition-specific preparation where training variables are manipulated to achieve desired objectives. New training interventions can improve best practice and enhance physical and skill development. Long-term physical improvements in emerging players require the implementation of effective resistance training programs.

**Purpose:** Establish the physical, physiological, technical and tactical demands of tournament competition (study 1 and 2), identify variables that influence the demands of small-sided basketball games to achieve specific training outcomes (study 3), determine whether the combination of flotation tank recovery and video-based training improves three-point shooting (study 4), and investigate online video-based resistance training for long-term physical development (study 5).

**Methods:** A combination of cross-sectional analysis of competition (seasonal vs. tournament) and training demands, and pre-post controlled trials were conducted. Data collection techniques included time-motion analysis, heart rate telemetry and video coding. Performance measures of on-court physical abilities, strength, functional movement (FMS) and three-point shooting were used to assess the effectiveness of specific training interventions.

**Results:**

**Study 1:** Running, sprinting and shuffling type movements occurred more frequently (8-15%, ±8%, mean, ±99% confidence limits) in seasonal games compared to tournament competition. Jogging, low and medium intensity shuffling decreased substantially by ~20% during the tournament. In contrast, the frequency of running, sprinting and high intensity shuffling increased substantially during the tournament. Players spent ~20% more time in moderate intensity heart rate zones in the tournament. Tournament competition had 16% fewer fast breaks and 8% fewer possessions per game.

**Study 2:** Success in senior and male World Championships was related to offensive performance indicators (2-point field goals made, free-throws made). Female and junior World Championship ranking was determined primarily by indicators of possession (turnovers, fouls, steals) and defensive pressure (defensive rebounds, blocked shots, turnovers), respectively.
Study 3: A lower number of players (2v2 versus 4v4) in a small-sided basketball game has moderate to very large effects on increasing physical, physiological and technical demands. Expanding court size and work-to-rest ratios elicits small to moderate physiological increases but lower physical and technical demands.

Study 4: Three weeks of flotation tank recovery combined with video-based training did not elicit larger improvements in successful three-point shots directly after the intervention (-2%, ±23%, mean, ±90% confidence limits), or the three week period post-intervention (-3%, ±18%) compared to a control group.

Study 5: Both supervised and online video-based training achieved 3-5% (±90% confidence limits, ±2-4%) greater improvements in several physical performance measures and a 28% (±21%) greater improvement in push up strength compared to a control group. Supervised athletes attained substantially larger gains in functional movement screening (FMS) scores (12-13%, ±8-10%).

Conclusions: Seasonal and tournament competition for junior basketball athletes appear to have substantial differences in physical demands. Scoring remains a key performance indicator in senior and male World Championships and should be a focus for the skill development of players. Coaches can manipulate different small-sided games to achieve specific training outcomes in basketball practice. Flotation tank recovery combined with video-based training did not improve three-point shooting. Online video-based resistance training is an effective form of program delivery. These findings identify factors that influence the competition-specific preparation of basketball athletes.
Chapter 1
Introduction

Success in basketball requires athleticism, mastery in a wide range of skills and a detailed knowledge of both team tactics and principles. The development of elite junior basketball athletes is multifaceted and focuses on improving physical, physiological, technical and tactical abilities. The term “elite” refers to these various abilities being of international standard and allowing the basketball athlete to compete in international competitions such as World Championships and the Olympics (4). To enhance these abilities, training must be individually tailored and directed towards specific competition demands. Furthermore, factors influencing the preparation and development of athletes need to be established for national coaching guidelines.

Competition demands

From a physical and physiological perspective, it is well established that basketball competition involves frequent changes in movement direction and intensity, regular jumping and repetitive sprints. An aerobic base is also required to maintain a high intensity work rate for the duration of the game (~1.5 h) (16, 97, 107, 139). Change of direction technique, muscular strength, vertical jumping ability, anaerobic and aerobic capacity are all important physiological qualities required for the physical demands of competition. The challenge is to develop optimal levels of these different and sometimes opposing physiological qualities that are specific to competition demands. Position-specific conditioning plans are also necessary. For example, guards require a larger aerobic capacity, and conduct more shuffling type movements and dribbling compared to forwards and centres (17, 123, 138, 139, 163). Furthermore, larger and taller players in the forward and centre positions need to focus on acquiring muscular strength and power necessary for their position-specific tasks, e.g. rebounding, sealing for position, and scoring.

Basketball typically involves two different forms of competition. Seasonal basketball competition lasts for 6-8 months with games on a weekly basis. Tournament competition predominately entails several games in a short time frame (e.g. 8 games in 10 days). World Championship and Olympic competitions are organised by the International Basketball Federation (FIBA) and played in a tournament format. The outcome of these international competitions determines a nation’s international ranking. However, the amount of research available on the physical and physiological demands of tournament basketball competition is scarce (103). Direct comparison of the physical,
physiological and tactical demands of seasonal and tournament competition, as well as identifying changes within a tournament, is needed to inform basketball coaches and support staff. This information would guide the establishment of competition-specific training objectives. Quantifying the effect of tournament demands on athletes may facilitate better planning for long-term athlete development (24).

In addition to competition format, the physical and physiological demands of a basketball game are influenced by several external factors including the tactics employed by the coach of the team, the style of play the opposition is executing, and the number of stoppages in play due to refereeing and/or level of competition. A better understanding of the physical and physiological demands of basketball competition requires analysis of the tactics commonly used in both tournament and seasonal basketball games. Quickly executed attacks, also known as “fast breaks”, as well as high pressure defensive tactics, have been associated with successful game outcomes (12, 133, 157). The number of high intensity fast breaks, the tactical elements within a slower style offence, and the duration of work-to-rest ratios within a game still need to be identified in modern elite basketball competition.

Coaches and athletes are interested in the most important technical skills required to be successful in international competition. Success in senior national competition has been attributed to defensive pressure, rebounding and field goal accuracy (53, 169). Analysis of the 2008 Beijing Olympic basketball tournament yielded similar findings (133). Unfortunately, little research exists on key performance indicators in junior basketball competition. The game is evolving quickly with recent rule changes including new extended three-point and key lines and shot clock regulations introduced in October, 2010. A cross-sectional analysis of the most recent World Championship box score data in under 17, under 19 and senior male and female competition would give a comprehensive overview of key performance indicators associated with a high ranking. This analysis will help prioritise the development of specific skills for basketball athletes, influence the national junior coaching curriculum, and highlight differences to preparing senior-level athletes for competition.

**Training methodology**

Once specific training goals that meet the demands of competition are established, training programs can be implemented that target the desired training outcome. Small-sided games are a common training tool in basketball practice and allow the
concomitant development of both conditioning and technical skills (47). While well established in a sport such as football (61), the variables that influence the demands and thus the training stimuli of a small-sided game are not well established in basketball. Reducing the number of players in a team can increase the physiological (cardiovascular) demands (27, 128), but the effect on the physical (movement frequency and intensity) and technical demands remains unclear. Additionally, the influence of different court sizes and work-to-rest ratios on the various demands in basketball have not been investigated to date. A controlled trial comparison between various small-sided games would clarify how the number of players, court size and different work-to-rest ratios influence the demands of game-based basketball drills. Establishing dose-response effects of small-sided games would assist coaches to adjust drills and practice sessions more precisely to achieve their desired training goal.

Shooting is a key skill required for all levels of basketball, with three-point shooting from the perimeter being one of the most difficult shooting tasks. While physical practice of three-point shooting is the most dominant form of practicing the skill, there may be alternative ways of preparing an athlete to perform this skill in competition. Some preliminary research indicates that both flotation tank recovery and video-based training interventions can improve basketball shooting (113, 148, 164). However, a combination of these two forms of visual rehearsal on three-point shooting has not been examined to date. The combination of both flotation and video-based training may be more effective than either intervention alone in improving skill acquisition. A pre-post controlled experiment will clarify whether an intervention combining flotation tank recovery and video-based training can elicit substantial improvements in shooting performance. Providing an effective training tool to improve three-point shooting would be of great value to players and coaches.

**Physical development and program implementation**

To ensure junior basketball players progress along an elite athlete development pathway, implementing physical resistance training programs at an early stage is essential. Resistance training under expert supervision can have a positive impact on physical performance in junior basketball athletes (136) and is safe (13, 41). The importance of strength, speed, vertical jumping ability and endurance for basketball athletes is highlighted by both coaches and researchers (37, 68). The lack of resistance training experience and expert supervision in junior athletes is related to many factors that may be overcome with an online video-based program delivery. To date, no
research has investigated the effects of a well-designed court-based resistance training program delivered online to junior basketball athletes. A pre-post experimental trial will clarify whether this type of intervention is effective in improving physical performance, strength and functional movement patterns in junior athletes. The findings from this research should guide the management and structure of program delivery.

**Statement of the problem**

Providing individual and competition-specific training programs relies on understanding the various demands of different basketball competitions. Despite several investigations describing the physical, physiological and tactical demands of seasonal competition, little is known of tournament competition. This shortcoming leaves coaches and support staff relying on anecdotal reports and personal experience when planning competition-specific training programs. Additionally, no research data exists on the key performance indicators of contemporary FIBA World Championships. It is therefore difficult to prioritise which technical skills and tactics should be addressed in the development of junior basketball athletes.

Precise planning of training requires evidence-based knowledge of the variables that influence the training demands in a practice session and across a season. Reducing the number of players in basketball small-sided games increases the physiological demands, but the effect of other variables such as court size and work-to-rest ratios in basketball training remains unknown. The effect of these variables on the technical and physical demands is also not well understood.

Improving shooting ability is a key focus for basketball coaches and athletes. Some evidence suggests that combining flotation tank recovery and video-based training could improve shooting ability. It remains to be investigated whether a combined intervention is effective in improving three-point basketball shooting.

Finally, long-term physical development requires the implementation of an effective resistance training program in the elite athlete pathway. Resistance training programs have shown to be effective in junior basketball athletes. The implementation of such programs is often difficult due to restraints in facilities and availability of expert coaches. An online video-based program may overcome these issues. Whether delivering resistance training in such a format yields positive benefits for junior basketball athletes needs to be established.
**Research aims**

A comparison of the physical, physiological and tactical demands of seasonal and tournament competition, as well as changes within a tournament, will establish competition-specific training objectives. An analysis of FIBA World Championship key performance data will help prioritise key skills and tactics required in international competition and guide national coaching curricula. Understanding the effects of number of players, court size and work-to-rest ratio on the physical, physiological and technical demands of small-sided basketball games will improve training methodology and completion of training objectives. As successful shooting is a crucial part of elite basketball competition, a novel intervention combining flotation tank recovery and video-based training may be useful to basketball athletes. To enhance the physical development of junior basketball athletes, online video-based resistance training programs may be an effective form of program implementation.

The specific aims for each experimental chapter of the thesis are:

1. **Activity profiles and demands of basketball competition**
   - Quantify and compare the physical, physiological and tactical demands of international tournament competition versus seasonal national-level competition in elite under 19 male basketball athletes.
   - Identify patterns of change in these demands within a tournament competition.

2. **A cross-sectional analysis of under 17, under 19 and senior male and female FIBA World Championships box score data**
   - Characterise relationships between final team rankings and box score data for junior (under 17 and under 19) and senior male and female FIBA World Championships.
   - Quantify differences in box score data between senior and junior, and male and female international World Championships.
3. Optimising technical skills and physical loading in small-sided basketball games

- Quantify the magnitudes of difference in physical, physiological and technical demands in various types of small-sided basketball games related to the number of players (2v2 versus 4v4), court size (half versus full) and work-to-rest ratio (4x2.5min vs. 2x5min).

4. Video-based training combined with flotation tank recovery to improve three-point shooting in basketball

- Assess whether the combination of video-based learning with flotation tank recovery improves three-point shooting performance in elite female basketball athletes.

5. Online video-based resistance training to improve the physical capacity of junior basketball athletes

- Compare the magnitude of improvement (change) in strength, functional movement patterns and physical performance of junior basketball athletes after six weeks of resistance training, employing either a fully supervised or an online video-based instruction program.

The overall purpose of this thesis is to improve the development of junior basketball athletes by investigating the specificity of preparation for competition. An overview of the key areas, research questions and studies is presented in Table 1.
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Chapter 2
Review of literature

Background

Basketball is a dynamic court-based sport that has gained world-wide popularity since its inception in the late 19th century. Worldwide, over 450 million people participate in basketball competition overseen by the international governing body FIBA (Fédération Internationale de Basketball) (78). There are several different forms of basketball competition run by national organisations and at international events conducted by FIBA. These events include regular 5v5 seasonal and tournament competitions, as well as newly-introduced 3v3 competitions.

Seasonal basketball competitions, predominately played in national leagues, are the main form of competition and income source for elite senior basketball athletes and organisations. The most well known national competition is the National Basketball Association (NBA) in the United States of America where median player salaries are $US 2.33 million per annum (3). Elite basketball athletes also compete in other well known national leagues in Europe (especially Spain, Portugal, Greece, Italy, Turkey and Germany), Asia and Australia. At a grassroots level, club and school teams predominately compete in seasonal competition. In addition to seasonal games, elite senior players compete at FIBA World Championships and the Olympics conducted every four years. These competitions are played in a tournament format and usually take place between seasonal competitions. A similar competition schedule exists for elite junior basketball athletes who compete in national seasonal competition for 6-8 months of the year and at under 17 and under 19 World Championships conducted every two years. The outcome of these tournament events at junior and senior levels determines a nation’s international FIBA ranking. High international rankings increase the profile of basketball and the level of government funding and sponsorship for the national basketball organisation.

Coaches and support staff need to understand the physical, physiological, technical and tactical demands their athletes face to prepare and compete successfully in these events. Generally, basketball is considered to have an intermittent activity profile involving a combination of stoppages, low and high intensity periods of play, frequent changes in direction and body movements, a multitude of technical skills including dribbling, passing, shooting, offensive and defensive footwork, and a tactical understanding of offensive and defensive principles of play.
Regular 5v5 basketball games generally consist of four 10 or 12 min quarters with two min rest between quarter time and a 15 min rest at half time. The clock is stopped during rule violations resulting in the “total game time” being longer than the “live playing time” of 40 or 48 min. Official FIBA competitions are played in 10 min quarters, whereas some national leagues, such as the NBA, have 12 min quarters. Court size also varies between FIBA, American college and NBA competitions. The standard international FIBA court size is 28 m long and 15 m wide (78). Different court sizes and playing durations can potentially alter the demands of the game. Following the principle of training specificity, training needs to be tailored towards the specific game demands for an effective transfer of training adaptations to improve competition performance.

Preparation of an elite basketball player must be directed towards specific competition demands. Movement patterns and physiological demands (through heart rate telemetry and blood lactate concentration analysis) have been investigated extensively in male and female basketball athletes in single seasonal games at a national domestic level (14-16, 18, 19, 79, 97, 99, 107, 123, 138, 139). These findings pertain to basketball games played on a weekly basis with sufficient rest periods (days) between games. A single basketball practice game can induce small decreases in 10 m sprint performance in junior basketball athletes (32). The demands of tournament competition are likely to differ as multiple games are played on consecutive days, minimising time for recovery between games. Three to four consecutive games in three to four days can induce fatigue and decrements in performance in basketball (103), handball (124), and soccer (125). International tournament competitions including the FIBA World Championships and Olympics involve up to 8 games played in a period of 10-14 days. The effects of consecutive games and minimal time for recovery on the physical, physiological and tactical demands are unknown, possibly hindering competition-specific preparation of basketball athletes. Additionally, many international tournaments are played at different age levels and in both genders.

Performance indicators differ between male and female competition and between competition levels in seasonal games (130). An open question in the basketball community is which performance indicators lead to success in international tournament competition in specific age groups and genders. Despite the importance of tournament competition for international success, preparation and development of elite basketball athletes is currently based on assumptions and uncertainty in the physical, physiological, tactical and technical demands.
Since preparation and training needs to be adjusted for specific competition demands, it is necessary for coaches to understand how to manipulate training variables. While small-sided basketball games are used by all basketball coaches, the influence of different variables on the demands of small-sided games has only received limited attention in the basketball research literature (27, 128). Clarifying how to manipulate small-sided basketball games is important for coaching staff to prepare basketball athletes for the specific demands of different types of competition. Understanding the physical and physiological demands of training drills also assists coaches with training load management and designing a progressive training program.

Shooting in basketball has been long identified as a key skill required at the elite level. While physical repetition and execution of shooting is common in basketball training, coaches and support staff are constantly seeking innovative methods to improve skill in elite athletes. Introducing effective interventions can assist a well-designed training program and provide a competitive advantage. However, the scientific literature on effective interventions to improve shooting performances is scarce and predominately in the field of visual imagery training combined with relaxation techniques (148, 164). To improve the preparation and development of elite basketball athletes, novel methods to increase scoring performances are required.

The foundation of all preparations for a specific competition is laid in the long-term development of basketball athletes. A major part of this long-term development is increasing the physical capacity of junior basketball athletes to create the resiliency required to handle high level training volumes and intensity (92). Despite resistance training interventions being effective in improving physical performances of junior athletes (134, 136), the physical abilities of Australian elite junior basketball athletes have been declining in the past (37). The implementation of resistance training programs at the junior level is difficult due to a frequent lack of resources, gym facilities and expert coaches. It needs to be determined whether resistance training can still be effective without expert supervision and expensive gym equipment.

**Competition demands**

Performances in basketball competition are impacted by various demands placed on the athlete. Research into the demands of basketball performance have included technical-tactical (53, 76, 133), fitness and anthropometric (38), as well as psycho-physiological and nutritional (168) aspects of basketball performance. While these findings generally
focus on an individual element of competition, athlete performances are multi-factorial in nature. Multi-dimensional approaches to competition and training are employed to yield greater insights into the various demands, their relationship to each other and overall performance (14, 154).

One of many challenges for team sport coaches and strength and conditioning staff is to provide individual and sport-specific training programs for different forms of competition. Conditioning basketball athletes in the past has relied heavily on coaching and playing experience. To gain insight into the specific demands of basketball, research studies need to include multiple aspects of performance.

Physical demands
Sport scientists have traditionally employed manual video-based time-motion analysis to measure the physical demands of basketball competition. This method of data collection and analysis is very time consuming, only permits a small number of games to be analysed, and prone to substantial intra- and inter-analyst variability. However, with the introduction of wearable sensor technology and automated video-based time-motion analysis, new and more valid insights can be obtained in the physical and physiological demands of basketball competition (122). Video-based time-motion analysis has been undertaken by several researchers to quantify the physical demands in basketball competition (18, 19, 79, 94, 97, 107, 138, 139). Most investigations have based their time-motion analyses in basketball on dividing a player’s movement into several distinct categories (stand/walk, jog, run, sprint, low, medium, high shuffle, jump) (97). One difficulty regarding notational time-motion analysis is obtaining acceptable reliability of the frequency and duration of events in these categories. While most authors state that reliability was tested through repeated analysis, only some report specific reliability data. Lower intensity movement patterns generally show good intra-tester reliability with an intra-tester coefficient of variation (CV) ranging between 2-4%, whereas higher intensity movement patterns become less reliable with CVs of 4-12% (18, 97, 138).

Despite the limitation of moderate reliability, it appears that a high number of movements (~1000 ± 100; mean ± SD) occur during a typical basketball game in both male and female athletes (18, 94, 97). More recent investigations adding dribbling and upper-body movement categories indicate that changes in movement intensity and patterns may have been underestimated, and the actual physical demands may be approximately twice as high (138, 139). There is a movement change on average every
~2 s (18, 94, 97, 138) involving frequent changes in direction with acceleration and deceleration of the body (79). Frequent changes in movement are also supported by the short duration of high-intense movements typically only lasting 1-4 s (18, 19, 97, 138) over the course of a 40-48 min basketball game. The percentage of time spent in these high intensity movements is relatively small in comparison to that of moderate or low movement intensities (18, 97, 107, 138). The existing findings regarding the physical demands of basketball games relate to seasonal national competition only. No research has investigated the physical demands of official tournament or international level competition. National level basketball athletes complete more total movements, and execute longer moderate to high intensity movements more frequently than state level athletes (14, 138). It is possible that the physical demands in international level competition, which is predominately played in a tournament format, are higher than national level seasonal games.

In addition to different competition formats influencing the physical demands, tactical strategies likely influence the frequency and duration of various movements. Man-to-man defensive strategies elicit 35% more sprinting, where as zone strategies involve 15% more high intensity shuffling movements, but the overall number of intense bouts is comparable between both defensive strategies (14). These findings relate to FIBA competition where zone defences are a common and a legal tactic. Physical demands may differ in competitions where zone defence is illegal (e.g. NBA). The influence of offensive strategies on the physical demands remains to be investigated as are differences in the tactical demands between seasonal and tournament competition. If tactical strategies differ substantially between these two competition formats, then physical preparation for a specific competition will need to account for the style of play (e.g. the frequency of fast breaks).

**Psycho-physiological demands**

Typical methods employed by sport scientists to quantify the psycho-physiological demands of team sport athletes have included heart rate telemetry, ratings of perceived exertion (RPE) and several measures of capillary blood metabolites such as lactate concentration. As physiological and psychological responses are interrelated, combining methods of physiological measurements and subjective ratings of exertion provide an integrated approach to assessing psycho-physiological loads of athletes. Most research studies use a combination of various psycho-physiological tools to evaluate the demands of basketball competition (105).
The introduction of heart rate telemetry systems has permitted scientists to directly quantify the cardiovascular demand of many sports including basketball. Heart rate monitoring has the practical benefit of being a non-invasive physiological measure and can be conducted continuously during training and competition. Measuring heart rate responses is a useful indicator of exercise intensity (65, 168). However, heart rate responses vary among individuals and are influenced by other variables such as nutritional status, hydration, environmental conditions, anxiety, psychological arousal, cardiac drift and stoppage in game play (168). Therefore, heart rate responses should only be interpreted as a general indication of exercise intensity.

Studies have reported high mean heart rate intensities of 82-95% of maximum heart rate (HRmax) during live time, and often a large percentage of total time (>75%) spent in heart rate zones above 85% of HRmax (15, 18, 94, 97, 123, 139). In some circumstances, high heart rates measured in high ambient temperatures (29-33 degrees Celsius) (15, 18), possibly overestimate the likely physiological demands under thermoneutral conditions. Basketball athletes are required to endure high levels of cardiovascular load for the duration of live playing time which seems contradictory in comparison to the small amount of time spent physically performing high intensity movements. However, the high cardiovascular demand is likely a result of the intermittent activity profile, additional exertion from upper-body movement, and static isometric muscle contractions (to maintain position) which increase the metabolic and physiological cost in team sport athletes (39, 56, 97).

Psycho-physiological demands seem to increase with the level of competition. More elevated RPE scores and salivary cortisol levels were measured following official seasonal games compared to practice games in elite male players (105). Mean relative heart rates are 4% higher in international competition compared with national competition and 5% higher in practice games in women’s basketball (123). Elite level players obviously need to be conditioned to maintain increased levels of intensity for longer periods of time. How the physiological demands in international level tournament competition differ to national seasonal competition remains unclear.

To determine metabolic demands, assessing blood lactate concentration is used to indirectly measure the activity of anaerobic glycolysis. Most research shows moderate levels of capillary blood lactate concentration during basketball competition ranging from ~3-12 mmol•l⁻¹ in male (18, 97, 107) and ~2-8 mmol•l⁻¹ in female athletes (94, 107, 123). Higher blood lactate concentrations were obtained in higher levels of
competition, and in real competition versus practice (123). The conclusion therefore is that the anaerobic glycolytic pathway is apparently utilised to a larger degree in higher levels of basketball competition. A higher concentration of free fatty acids and triglycerides concentrations have been measured in the bloodstream through the latter periods of the game suggesting that, with increasing fatigue, aerobic energy systems come into play (15). These findings need to be interpreted with caution as lactate measurements reflect the activity of the last few minutes prior to blood sampling and may not mirror high intensity movements at earlier stages in the game (155). Nonetheless, the challenge for the coach remains to simultaneously develop an optimal degree of aerobic and anaerobic fitness.

The existing findings on the physical and psycho-physiological demands of basketball provide useful guidelines for the conditioning of basketball athletes for seasonal competition. All studies investigating single seasonal games in a variety of levels of competition have emphasized the importance of agility, anaerobic capacity and highlighted positional differences (18, 97, 139). Unfortunately, little research has investigated the physical and psycho-physiological demands of multiple games played in a tournament style format. A three-day mini tournament induced small to large increases in muscle damage markers and inflammatory cytokines in well-trained basketball players (103). Official matches elicit ~twofold increases in cortisol and ~40% higher RPE scores than simulated matches (105). As official international tournaments are played for 8-10 days, tissue damage and metabolic disruptions are possibly higher than levels reported in seasonal competition. Information on the demands of tournaments is important for coaches to condition their athletes towards this competition format. Only one study has investigated the physiological demands in international competition in women’s basketball (123). Further investigation into the physical and psycho-physiological demands of elite international tournament play is necessary to improve basketball-specific training programs.

**Analysis of technical and tactical demands**

While measuring the physiological and physical demands is one method of assessing a basketball game, coaches are also interested in the technical and tactical elements of a game that differentiate winning from losing teams. During basketball competition, specific elements of the game are notated and statistically described to the coaches as “box scores”. This information is used for game management and tactics but also guides the long-term development of certain skills and team plays. The most common data
presented in box scores are field goals (2-points)-made, -attempted, -percentage, 3-point shots-made, -attempted, -percentage, free-throws-made, -attempted, -percentage, offensive and defensive rebounds, assists, turnovers, steals, blocks and fouls (88, 133). Box score data is presented to coaches throughout the game and provides immediate feedback on individual players’ and the team’s performance in key areas.

The key discriminating factors of winning teams are defensive rebounds, number of successful free-throws and field goals (34, 50, 53, 74, 76, 131, 133, 156). Other box scores such as offensive rebounds, steals, turnovers and assists are not consistently reported as discriminating factors between winning and losing teams in seasonal competition. The importance of other box score variables becomes more evident when other factors such as game location (home vs. away), gender and level and type of competition (130) are included. In away games, in addition to field goals made, less unsuccessful 3-point shots discriminate winning teams (50). Similarly, successful 3-point shots discriminated teams after three consecutive games (74). It appears that successful perimeter shooting is an important factor in a variety of circumstances. In women’s basketball competition and starting players, assists have also been identified a key factor to success (51, 52).

When investigating teams’ success over a whole season (defined by team ranking at end of a regular season), rather than a single game outcome, more successful teams are differentiated by a higher number of assists, steals and blocks (75). Teams with better overall passing skills, and outside and inside defensive pressure, are more likely to be successful over a whole season and in women’s basketball. Most studies have investigated box score data from seasonal competition. Little is known of the key discriminating factors in tournament competition. Defensive rebounding, free-throw percentage, as well as field-goal percentage and number of three-point attempts have been identified as discriminating factors in junior World Championship and European Championship tournament competition (34, 76). A comparison of gender and level of competition in World Championships showed that male tournaments included more blocks and less unsuccessful field goals, whereas more assists and less turnovers occurred in senior versus junior World Championships (130). While these studies indicate gender and level of competition differences, they do not directly identify which performance indicators are associated with successful rankings in the respective tournament. The key performance indicators of recent World Championships at under
17, under 19, senior and in female competition are unknown. This information is required to guide contemporary coaching guidelines and practices.

Since different styles of play can potentially lead to the same performance outcome, making conclusions in regard to the most successful tactical strategies from game statistics is problematic. In an analysis of 90 seasonal Greek senior elite men’s games, winning teams initiated offence through defensive rebounds ~4% more frequently than losing teams and had 1.3% more fast breaks (158). The importance of fast breaks for winning seems to be equally important in modern seasonal competition (157). That a higher number of fast breaks result in higher field goal percentages is likely (12, 140), but remains speculative. Since a high percentage (83-97%) of fast breaks are initiated through defensive rebounds or steals (140, 157), the possibility to achieve a high number of fast breaks seems to be dependent on a team’s ability to exert defensive pressure. This notion is supported by Team USA’s dominance at the 2008 Beijing Olympics (133). Recovered balls per ball possession as a defensive performance variable and effective field goal shooting were the discriminating factors for this team’s success. Hence, defensive patterns of play seem to have an important role not only in hindering the other team from scoring, but also enabling high scoring opportunities in both seasonal and tournament competition. While man-to-man defence in the quarter court was the most common and successful defensive pattern of play in elite Greek seasonal basketball competition in the mid to late 90’s (158), both man-to-man and zone strategies were equally employed in more recent junior seasonal games (14). The choice of defensive systems is largely dependent on the type and level of opposition and may therefore vary between competitions. Furthermore, while fast breaks enable successful scoring opportunities, a larger proportion of the game is played using a slower pace set offence (12, 157). However, in regard to the efficiency of different elements of set offences, research findings are lacking. An analysis of the ‘inside game’ (i.e. scoring near the basket) in European and North American (NBA) seasonal basketball competition supports the importance of an ‘inside-outside’ (i.e. passes coming from close to the basket to the perimeter) game in set offensive patterns of play (95). The effectiveness of other patterns of play, e.g. on-ball screens, dribble penetration and off-ball screens, remains uncertain in both seasonal and tournament competition.

Training methodology

Even when training objectives are specific and individually planned, they can be difficult to achieve in a team training environment given the numerous variations in
number of players, court size and work-to-rest ratios. To achieve desired training outcomes and plan periodised programs, it is necessary to understand the influence of basketball training drills on the physical, physiological and technical demands. The effect of basketball practice (67, 153, 159) and strength training interventions (20, 57, 67, 134, 167) on specific basketball performance variables has been well documented. However, the demands of common training drills and exercises, such as small-sided games and shooting drills, remain relatively unknown.

Tri-axial accelometry data from offensive and defensive training drills indicates that the physical demands are higher in offensive compared to defensive drills, however oxygen demand is substantially higher in defensive drills (102). Further support of the higher physical demands in offensive drills is indicated by increased capillary blood lactate concentrations (8.2 ± 4.6 mmol•L⁻¹; mean ± SD) and muscle damage markers (a ~6-fold increase in creatine kinase, 0.5-fold increase in lactate dehydrogenase and 24-fold increase in myoglobin) after 10 min of a selected basketball shooting drill in healthy recreational male basketball players for up to 48 hours post-exercise (86). These findings give an indication of the physiological effect of various basketball activities, but little insight on how training drills can be manipulated to achieve specific physiological responses.

Small-sided games in basketball

A common form of basketball practice is the use of small-sided games also known as game-based conditioning. Suggested benefits of game-based conditioning include greater transfer of physiological adaptations where exercise simulates sports-specific movement patterns, athletes develop simultaneously technical and tactical skills under high physical loads (47), and higher motivation of athletes performing sport-specific rather than traditional conditioning (146). Sport-specific conditioning can provide a similar or perhaps greater increase in physical fitness than traditional conditioning drills. Substantial improvements in both skill execution and conditioning with small-sided games are likely to promote overall improvements in performance (44, 47, 61, 146).

Sport-specific conditioning in the form of small-sided games has been evaluated extensively in field-based team sports such as soccer (see review (61) and rugby (44, 48, 49), but less so in court-based sports such as handball (23) and basketball (27, 128). The small number of research studies on basketball training is surprising given the almost universal use of small-sided games in both junior and senior programs. Given the likely
benefits of small-sided games in basketball practice in improving both skills and conditioning, it is important to characterise (under controlled conditions) variables of training prescription that influence the relative contributions of the physical, physiological, and technical demands of various small-sided basketball games. The design of small-sided basketball games defines the balance between physical and physiological demands and technical practice needed for competitive success.

Several factors that influence the physiological, physical and technical demands of small-sided games, and thus the desired training stimulus from game-based conditioning, have been identified in soccer (61). To increase the number of technical actions per player in soccer, reducing the number of players has more of an effect than adjusting field dimensions (35, 82, 115). However, having smaller team sizes increases the physiological and physical intensity of a small-sided soccer game (35, 60, 62, 81, 85, 120, 165). The most extensive investigation showed that heart rate (~4%), blood lactate concentration (31%) and RPE responses (21%) increase substantially with a reduction in team size from 6- to 3-a-side games (120). Another factor to consider is the effect of intermittent and/or continuous small-sided games. High intensity movement patterns occur longer and more frequently in intermittent small-sided soccer games, where as heart rate and perceived exertion responses are higher in continuous formats (63). These findings provide some guidance towards the possible physiological demands of various small-sided games in court-based sports. However, there is less information on the physical demands associated with small-sided games in general (60, 62, 63). Moreover, these demands are likely to be different in court-based sports like basketball given the differing technical requirements and smaller playing area.

A decrease in team size from 5v5 to 2v2 on a full basketball court, thus increasing the relative court area, increases heart rate (~8%), VO$_2$ (~10%), blood lactate concentration (~85%) and RPE responses (~50%) (27). Increased physiological demands are also observed when the number of players is reduced while keeping the relative court area consistent in the half court (128). Full court basketball practice games elicit larger physiological responses (~12% higher mean heart rate) and moderately higher physical demands (85% higher accumulated load) than half court 5v5 scrimmages (102), suggesting that a larger court area should increase physiological and physical demands in small-sided basketball games. Which of these two variables (number of players or court size) has the largest effect on the physiological demands and their influence on the physical and technical demands in basketball remains unclear.
Existing studies only provide limited information on how the number of players, court size and different work-to-rest ratios influence the demands of small-sided basketball games (an overview is shown in Table 2). The research investigating the demands of game-based conditioning for basketball is limited to the influence of the number of players on cardiovascular and RPE responses. Court size increases heart rate and physical workload in 5v5 scrimmages (102), but the effect of court size with smaller team sizes remains unknown. Further research is needed to clarify the influence of the number of players, court size and work-to-rest ratios on the technical and physical demands in small-sided basketball games.

Table 2 – Outline of small-sided game variables and their influence on the demands of small-sided basketball games.

<table>
<thead>
<tr>
<th>Demand</th>
<th>Variable</th>
<th>Number of Players</th>
<th>Court Size</th>
<th>Work-to-Rest Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>Physiological</td>
<td>↑(\downarrow)</td>
<td>↑(\uparrow) (?).</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>Physical</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td></td>
</tr>
</tbody>
</table>

Arrows indicate direction of influence as known from current research findings in basketball. Left arrow indicates increase or decrease in demand, right arrow indicates increase or decrease in variable. Question marks indicate gaps in basketball research.

In basketball, most drills and small-sided games are conducted in either half of the court, or the full court with one to five players on a team, and a duration of approximately 5-10 min (102). Understanding the influence of training variables on the physiological, physical and technical demands of small-sided games in basketball will improve the prescription of game-based conditioning in basketball practice.

Shooting interventions

Successful shooting is paramount to success in basketball and related to the time players spend on the court (129). Shooting in basketball received early attention in both coaching and research (118, 151, 152). Most research in regard to this skill has investigated the kinematics of shooting and guided explicit instructional coaching. Key factors that influence the kinematics of shooting have been identified in jump shots (73, 98, 100), free-throw shooting (59, 137, 152) and three-point shots (40). In general, sound shooting technique involves a straight and high release of the ball with backspin (118, 151). Shoulder, elbow and forearm position need to be in line and form a shooting plane with strong wrist flexion enabling a consistently accurate projection of the ball
A release angle between 50-60° above the horizontal plane is required for optimal shooting accuracy (73, 84, 100). However the optimal shooting angle depends on anthropometric characteristics (i.e. player’s height) and the distance from the basket. Shooting angles decrease and ball velocity increases with longer shooting distances (73, 84, 100). In longer distance shots, decreased shooting angle reduces the scope for error of the ball’s entry into the basket (98, 112). However, a lower shooting angle also reduces the energy cost required for an increased ball velocity (73), which is also associated with a larger margin for error. Movement kinematics in three-point shooting in a professional basketball player change with increasing levels of fatigue (40). The key for successful shooting is to develop consistent movement techniques, permitting an optimal release angle that can be adjusted according to shot distance and fatigue level.

Evidence-based training interventions for shooting are scarce despite the importance of shooting for basketball performance. One study has reported performance increases in basketball shooting by increasing sleep volume in collegiate basketball athletes (91). Flotation tank recovery and video-based training are two treatment methods employed to leverage skill acquisition in various performance tasks including basketball shooting. Both treatment methods have been used separately to improve skill in aiming tasks (e.g. rifle marksmanship, archery, darts, basketball free-throws), but no study has investigated the effectiveness of a combined approach.

Flotation tank recovery entails an athlete lying supine in a water-filled, light and sound reduced tank. The tank contains a saline solution which allows the athlete to float. This “restricted environmental stimulation therapy” (REST) has been investigated and reviewed as a relaxation and stress-management tool (161). Positive effects from flotation tank recovery include reduced muscle tension, lower symptoms of stress and improved information absorption (147). Increasing internal focus and primary-process orientation may be important for closed-skill execution (109). Several investigations have reported positive benefits in aiming tasks following single (9, 109, 148, 149) or multiple (89, 96, 164) exposures of flotation tank recovery, sometimes combined with imagery training. Earlier studies including visualisation procedures combined with flotation tank recovery reported better improvements in performance versus imagery training alone (89, 96, 148, 164). It is unclear whether these performance improvements were a result of flotation tank recovery alone or if the combination with imagery training was necessary. Subsequent studies indicated that improvements in athletic performance can be mostly attributed to the flotation tank recovery (9, 109, 149). One
study demonstrated a 37% improvement in basketball free-throw shooting (148) and another increases in overall basketball performance in competition (164) following flotation tank recovery combined with imagery training. It appears that flotation tank recovery may be a useful tool to improve basketball shooting performances. Whether these treatments are effective on other forms of shooting such as the three-point shot, or with more skilled players in an elite training environment, needs investigating.

An additional form of mental training that has been investigated to improve basketball shooting is video-based training which combines Visuo-Motor Behaviour Rehearsal (150) with displaying a video-taped model performer. Visuo-Motor Behaviour Rehearsal is a combination of relaxation and imagery techniques and can improve free-throw accuracy without a video-recorded model (Kolonay 1977 cited in (55). While this study showed an improvement with Visuo-Motor Behaviour Rehearsal alone, other research indicates that performance improvements are higher with video-based training (55, 58, 113). In higher skilled athletes, video modelling alone may be more effective in improving free-throw shooting (113). These studies have several limitations in methodology (55), data presentation (58) and result interpretation (113). The effectiveness of relaxation techniques combined with video modelling to improve shooting in elite basketball athletes remains to be substantiated.

In theory there might be benefits from flotation tank recovery which can increase internal focus and primary-process orientation through a reduction in external stimuli, and video-based training for three-point shooting in elite level basketball athletes. No previous research has examined the effectiveness of this combined approach in basketball shooting. A combination of interventions may improve three-point shooting of individual players, and consequently a team’s overall performance.

**Developing physical capacity and program implementation**

Increasing the physical capacity of junior basketball athletes is crucial for the preparation of the demands of elite training and competition. Elite basketball athletes differentiate themselves from sub-elite athletes by superior physical performances (37, 64). High maximum leg strength values are associated with increased court time (68) and basketball-specific fitness measures (29). The importance of physical development is also highlighted with abdominal strength and aerobic capacity being positively correlated to basketball skills in young players (30). Providing an early introduction to physical training builds training experience associated with physical performance in
junior basketball athletes (25, 26). Unfortunately, a decline in the physical performances of elite junior basketball athletes in Australia has been identified previously (37). Supervised resistance training for junior athletes improves musculo-skeletal characteristics, reduces injury risk and enhances motor performance (41). The long-term development of junior basketball athletes should provide a conditioning program incorporating resistance training to increase the physical capacity required for elite basketball.

Several factors can hinder the physical development of junior athletes including a decline in physical activity within the general adolescent population (110). Basketball training alone can improve aerobic fitness levels and reduce percentage body fat (159). However, substantial gains in muscle strength or joint mobility are difficult to achieve without resistance training (159). Resistance training interventions are required to compensate for the apparently decreasing level of physical capacity in many junior athletes. Many investigations have demonstrated positive enhancements in physical performance following short-term resistance training in young adolescent basketball athletes (20, 22, 134-136). Furthermore, fatigue as a result of poor fitness increases the risk of injury (46) and results in poor skill execution (45, 126). Poor functional movement is also linked to a higher injury risk (83). Therefore, enhancing basketball athletes’ physical condition and functional movement capacities is important for reducing fatigue effects and risk of injury. Large improvements in strength, but smaller improvements in vertical jumping of collegiate-aged athletes, have been reported after a four year college career (72, 119). Clearly improvements in physical performance require a substantial amount of time and resources. An early introduction to resistance training is necessary to improve the physical performances in junior basketball athletes.

Expert supervision and well-designed programs that take a young player’s maturation and training history into account are recommended by National Strength and Conditioning Associations and the Canadian Society for Exercise Physiology (7, 13, 41). Gym equipment is often difficult to access, and resistance training can be impractical and should not be used by novice athletes without expert supervision (41). Conducting body-weight resistance training on the basketball court before, after or as part of a basketball training session would be a practical solution. Increased upper-body endurance has been demonstrated following an on-court circuit program, but lower body power and trunk strength endurance did not improve more than basketball training alone (20). The lack of increased improvement in lower body power and trunk strength may
be due to limitations in the program design which predominately included plyometric and strength endurance exercises. It is therefore unclear whether a body-weight resistance program including exercises that emphasise functional movement patterns and dynamic strength on the basketball court is effective in improving physical performance in junior basketball athletes.

Providing resistance training interventions for a larger and remote athlete population with limited resources and expert strength coaches is a challenge for most sporting organisations. Implementing well-designed resistance training programs to athletes at an earlier stage in their development may be achievable with an online video-based program (e.g. VisualCoaching Pro®) delivery without expert supervision. Online physical activity interventions have been applied to a sedentary adult population and yielded some benefits in increasing the amount of physical activity (160, 162). Many online intervention programs have utilised interactive elements such as email, online coaching and videos. Unsupervised strength training programs for adolescent rugby athletes without media interaction have showed positive benefits, although these have been mostly smaller in magnitude when compared with supervised training (33, 143). In theory, an online video-based program that can be conducted on an easily accessible basketball court and includes body-weight resistance exercises may be an innovative method to improve the physical capacity of junior basketball athletes.

Summary

Several questions in regard to the physical, physiological and technical development of junior basketball athletes remain unanswered. The differences in seasonal and tournament competition demands remain unclear, hampering the design of specific training plans. The key determinants of successful performances in modern international basketball competition need to be established to guide contemporary coaching practice, national coaching curriculums and technical-tactical skill development. To prescribe specific training programs, the magnitude of the effect of discrete variables that influence the demands of basketball training drills need to be understood more clearly. Small-sided basketball games are a popular training tool, but how the number of players in a team, court size and different work-to-rest ratios affect the physical, physiological and technical demands of these drills requires attention. Field-goal percentage is a critical element of competitive basketball and improving shooting ability is a key focus in basketball practice. Flotation tank recovery combined with video-based training may be an effective intervention to improving basketball shooting that has not been
investigated previously. The effectiveness of an online video-based resistance training program in improving junior basketball athletes’ physical performances needs to be explored. This type of program delivery may offer a practical solution to provide an early introduction of resistance training in the player development pathway.
Chapter 3
Tournaments include multiple games in a short period (e.g. eight games in 10 days) and likely place different demands on basketball athletes compared to seasonal (weekly) games. The demands of tournament and seasonal competition need to be established for competition-specific preparation and development of elite basketball athletes. The following study compares the physical, physiological and tactical demands of seasonal and tournament competition, and investigates changes in demands during the course of an international under 19 tournament.
Activity profiles and demands of seasonal and tournament basketball competition

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Abstract

Conditioning for seasonal and tournament basketball games is challenging, as the demands of the two formats are not well characterized. **Purpose:** To compare the physical, physiological and tactical demands of seasonal and tournament basketball competition, and determine the pattern of changes within an international tournament. **Methods:** Eight elite junior male basketball athletes (age 17.8 ± 0.2 y, height 1.93 ± 0.07 m, mass 85 ± 3 kg; mean ± SD) were monitored in six seasonal games played over four months in an Australian second-division national league, and in seven games of an international under 19 tournament played over eight days. Movement patterns and tactical elements were coded from video and heart rates recorded by telemetry. **Results:** The frequency of running, sprinting and shuffling movements in seasonal games was higher than in tournament games by 8-15% (99% confidence limits, ±~8%). Within the tournament, jogging and low to medium intensity shuffling decreased by 15-20% (±~14%) over the seven games, while running, sprinting and high intensity shuffling increased 11-81% (±~25%). The total number of possessions was higher in seasonal than in tournament games by 8% (±10%), but there were unclear differences in mean and peak heart rates. Ball reversals and off-ball screens were the most frequent events in both types of competition. **Conclusions:** Assuming these data are representative of junior elite competitive basketball, coaches should consider adjusting conditioning programs towards the higher activity of seasonal games, and employ strategies that alleviate the effects of fatigue and account for the lower number of possessions in tournaments.

**Keywords:** domestic competition, physiological demands, physical demands, tactical demands, game analysis
Introduction

The development of elite junior basketball athletes needs to be tailored towards the physiological, physical, and tactical demands of seasonal domestic competition or tournament-style international competition or both. A targeted training program is best planned and implemented if the specific demands of domestic and international competition are well characterized. Several investigations have described the physical and physiological demands of seasonal competition (14, 16, 18, 19, 79, 94, 97, 99, 107, 123, 138, 139, 163) where players typically play one game each week, but no research has examined a full tournament involving multiple games in a seven to ten day period. The lack of research in tournament competition is surprising considering this format is followed in international championships sanctioned by the International Basketball Federation (FIBA).

The physical demands of seasonal basketball games have been primarily investigated through time-motion analysis quantifying various low to high intensity movement patterns. Typically, ~1000 ± 100 (mean ± SD) changes in movement and intensity occur during seasonal basketball competitions in male athletes (18, 97). Movement changes are recorded on average every 2-3 s (18, 94, 97) often involving frequent changes in direction and rapid deceleration and acceleration (79). Movement demands may be more strenuous than previously estimated when including upper-body movements, dribbling, static exertion, and using frame-by-frame time-motion analysis (14, 138). Higher movement intensities have been observed in higher levels of seasonal competition (138) and in international-standard players (14). In contrast, the physical demands of international tournament competition remain unclear.

Basketball athletes generally maintain high mean heart rate values (>85% of maximum) for the majority of live playing time (16, 97, 139). Higher mean heart rate values are exhibited during international-level compared to national-level female competition (14, 123), however the physiological demands of elite male competition have not been investigated. The effect of tournament competition on physiological demands estimated via heart rate monitoring remains to be investigated. Characterizing changes in heart rate over several consecutive games should give insight into the physiological demands experienced during tournaments.

Successful teams typically have more successful field goals and defensive rebounds than their opponents (34, 53, 76, 131, 156). The tactical elements that lead to this
advantage remain uncertain. It appears that winning teams gain more defensive rebounds facilitating more fast breaks (158). The importance of fast breaks for winning seems to be equally important in modern seasonal competition (157). While fast breaks increase scoring opportunities, a larger proportion of the game is played using a more controlled set offence (12, 157). Only limited research has been conducted on the effectiveness of different elements of set offences. The use of an “inside-outside” game in set offensive patterns of play is important to increase scoring opportunities (95). The frequency and value of other patterns of play remain to be investigated. A comparison of the different styles of play between the two competition formats should provide useful tactical information for coaches and support staff.

International basketball competition predominately involves a tournament-style competition format. Tournaments are characterized by a large number of games in a short time period. Despite the importance of international championships and rankings, no investigation to date has examined the various physical, physiological and tactical demands of this competition format. Differences in demands between seasonal and tournament competition, as well as changes over the duration of a tournament should reveal important information for the preparation towards a specific competition.

The aim of this study was to quantify and compare the physical, physiological and tactical demands of international tournament competition versus seasonal national-level competition in elite under 19 male basketball athletes. A secondary aim was to identify patterns of change in these demands within tournament competition. Understanding the demands of international championships will allow coaches and support staff to better implement long-term preparation plans around seasonal demands, as well as strategies within a tournament.

**Methods**

The experimental design comprised a cross-sectional (seasonal versus tournament competition) and longitudinal (changes in demands within tournament competition) study of elite male junior basketball competitions. Data were collected from a seasonal national men’s 2nd division winter competition (2010 South East Australian Basketball League, Australia) and an international tournament (2010 Albert Schweitzer Tournament, Mannheim, Germany). A total of six national seasonal (all home games) and seven international tournament games were analyzed. The seasonal games were played at least one week apart over a four month period, and the tournament games
within an eight day period. Both competition types used the same game format with 4x10 min quarters and equal rest periods. Data were analyzed to compare the two competition formats, as well as changes within international tournament competition.

Subjects
Eight elite junior male basketball athletes (age 17.8 ± 0.2 y, height 1.93 ± 0.07 m, mass 85 ± 3 kg; mean ± SD) were members of both teams that competed in the national league and international tournament. These players had obtained a basketball scholarship at the Australian Institute of Sport (AIS). Players typically completed over 20 hours of training per week and competed at the highest level in national junior competition. Ethical approval was given by the AIS Ethics Committee, approval number 20090805. Informed (parental) consent was obtained from all participating subjects.

Procedures
The physical, physiological and tactical demands of games were quantified through time-motion analyses, heart rate telemetry and video coding software. Heart rate profiles were captured through heart rate telemetry (Suunto™, Vantaa, Finland). Heart rate data were analyzed for total game time (including time outs, substitution, quarter and half times) and active playing time (only including heart rate data above 70% of individual maximum heart rate). Rest periods were not excluded from total game time in agreement with previous studies (16, 18, 94, 97, 139) to incorporate the effect of rest periods on the physiological demands. Values were expressed as the mean and peak heart rate as a percentage of each subject’s individual maximum heart rate (HRmax), time spent in Zone 1 (50-59% of HRmax), Zone 2 (60-69% of HRmax), Zone 3 (70-79% of HRmax), Zone 4 (80-89% of HRmax), and Zone 5 (90-100% of HRmax). HRmax was determined during the Yo-Yo Intermittent Recovery Test Level 1 (8) conducted prior to commencement of the study as part of routine physical testing.

Physical and tactical demands were quantified by manual notational video analysis using specialist sports coding software (SportsCode Elite, Sydney, Australia). The physical demands were coded as the following movement patterns: stand-walk, jog, run, sprint, low, medium and high intensity shuffle and jumps (18, 97). Our time-motion analysis showed moderate to good reliability with typical errors ranging between 4-15% and intraclass correlations (r) from 0.68-0.93 across the different movements. Briefly, jogging was defined as forward movement involving a flight phase without urgency, while running involved moderate urgency and a more pronounced arm swing. Sprinting
efforts were forward movements with high to maximal intensity. Shuffling was defined as any sideways or backwards movement from low to high intensity.

Tactical demands were quantified as the number of offensive technical elements within a game. The elements within offensive possessions were coded as outlined in Table 3. Both teams employed the same coaching staff and tactical strategies in seasonal and tournament competition allowing a comparison of the tactical demands between the two competition formats. Duration of each possession for the home and opposition team and the transition time between possessions were used to calculate work-to-rest ratios. The total duration of multiple possessions with a short transition phase (<30 s) was determined as a “playing period”. A time exceeding 30 s between possessions was defined as a “break period”. Possessions with durations below 8 s were defined as a “fast break”, indicating a quick transitional style of play.

**Table 3 - Tactical elements coded during offensive possessions to evaluate tactical demands of seasonal and tournament basketball competition**

<table>
<thead>
<tr>
<th>Element</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball reversal</td>
<td>Defined as ball movement from one side of the court to the other. An imaginary line between both baskets, often referred to as the “splitline”, is used to divide the court into two sides. Every ball movement across this splitline was considered a ball reversal. Ball reversals force the defense to move from one side of the court to the other, enabling better scoring opportunities.</td>
</tr>
<tr>
<td>Dribble penetration into the key area</td>
<td>A player dribbling or receiving the ball off a cut with at least one foot inside the key area was defined as dribble penetration.</td>
</tr>
<tr>
<td>Post entry</td>
<td>The post is a position on the court around or in the key area. A pass from another position to the post area is defined as a “post entry” that increases the likelihood of scoring opportunities close to the basket.</td>
</tr>
<tr>
<td>On-ball screen</td>
<td>Offensive pattern involving a player standing in the way of a teammate’s defender who is guarding the ball carrier. The teammate who is carrying the ball can then separate from his defender while dribbling the ball to create an offensive advantage.</td>
</tr>
<tr>
<td>Hand off</td>
<td>Similar concept to on-ball screen where an exchange of the ball between players occurs by directly handing over the ball to a team mate.</td>
</tr>
<tr>
<td>Off-ball screen</td>
<td>Involves an offensive player standing in the way of a teammate’s defender. This screening action allows the other offensive player to separate from his defender.</td>
</tr>
</tbody>
</table>
**Statistical Analysis**

Player movement, heart rate data and tactical elements were analyzed with a Poisson regression model that accounted for any linear time-dependent trends during the season and within the tournament. Values at the midpoint of the tournament were estimated for comparisons of seasonal versus tournament competition. Movement counts and heart rate data were expressed per 30 min of movement time to allow comparisons between and within competitions, and tactical elements were standardized to 100 possessions to account for differences in game rhythm.

Inferential analyses were based on uncertainty in magnitudes of effects to overcome the shortcomings associated with traditional statistical significance testing (11). Uncertainty in effects is indicated with 99% confidence limits. Effects were deemed unclear if the confidence interval overlapped the thresholds for smallest important increases and decreases of counts or durations, which were assumed to be 10% (a factor of 1.10) (70). Smallest important changes for peak and mean heart rate values (expressed as percent of HRmax) were 0.5% and 1% for peak and mean heart rate respectively, which were approximately $0.2 \times$ between-subject standard deviation (70). Magnitudes of clear effects were described probabilistically using the following scale: possibly 25-75%, likely 75-95%, very likely 95-99.5%, and most likely >99.5% (71).

**Results**

All games played by the Australian team at the Albert Schweitzer tournament were highly competitive. The team lost one game by 5 points at the start of the tournament but managed to win all other games with close margins and finished the competition in first place. Seasonal games were mostly competitive with the team winning two games and losing two by close margins (point differential <12 points). Two games in the seasonal competition were lost by slightly larger margins (17 and 23 points). A summary of the descriptive mean and standard deviation data for the physical, physiological and tactical demands is shown in Table 4 for both seasonal and tournament competition. For the tactical demands, possession, rest, playing and break duration refer to the cumulative mean duration of both teams’ possessions, i.e. mean durations for every possession of the game. All other tactical elements refer to the investigated team only. Possession and rest durations are standardized to one possession. Playing and break durations are standardized to one count of playing and break periods.
Physical demands

The difference in total movement counts at the mid-point of the tournament was trivial (-7.1%, ±3.8%; mean, ±99% confidence limits) between season (788, ±43) and tournament (732, ±40) competition. Running, sprinting and low to high intensity shuffling type movements occurred more frequently (8-15%, ±~8%) in seasonal games compared to tournament competition (Figure 1). Differences in other movement categories between the two competition formats were trivial. Substantial decreases during the international tournament occurred in jogging, low intensity and medium intensity shuffling. Conversely, the frequency of running, sprinting and high intensity shuffling increased substantially during the tournament (Figure 2).
Figure 1 – Standardized differences (%) in physical demands of seasonal and tournament basketball competitions. The differences are derived from the means and SD as shown in Table 4. Shaded areas indicate thresholds for magnitude of effects.

Figure 2 – Change (%) in movement counts during an international junior basketball tournament competition. Shaded areas indicate magnitude of effect.
**Physiological demands**

Thirty-four heart rate data sets were incomplete due to belts falling off during games. Only complete game files were analyzed from six players with a total of 75 individual heart rate data sets. Peak heart rate values were possibly different between seasonal (94% ± 3% HRmax; mean ± SD) and tournament (95% ± 2% HRmax) competition. There were possible differences in mean heart rate between the two competitions for total game time (seasonal, 67.1% ± 6.6% vs. tournament, 68.1% ± 5.8% HRmax) or active playing time (seasonal, 84.3% ± 1.8% vs. tournament, 83.9% ± 2.3% HRmax). When comparing time spent in different heart rate zones, players likely spent 32% (±99% confidence limits, ±17%) more time in Zone 1 and possibly 7% (±12%) more time in Zone 4 in seasonal, but possibly 11% (±16%) more time in Zone 2 and 12% (±14%) more time in Zone 3 in tournament competition. No clearly substantial difference in time spent in Zone 5 was evident between the competition formats.

There was no clear change in peak heart rate over the duration of the tournament and clearly trivial changes in peak heart rate during the season. In contrast, the mean heart rate during active playing time possibly increased (1.4%, ±1.8%) by the end of the tournament. The higher mean heart rate coincided with a likely 30% (±29%) increase in time spent in Zone 4 and a likely 21% (±17%) decrease in time spent in Zone 3 during the tournament.

**Tactical demands**

The mean duration of a possession in seasonal competition was 7% (±99% confidence limits, ±9%) shorter than the tournament competition. The mean rest duration between possessions was also 20% (±27%) shorter in seasonal than tournament competition. Accordingly, the total number of possessions was 8% (±10%) higher in seasonal competition compared to tournament competition. The higher number of possessions corresponds with 16% (±13%) more fast breaks (possessions < 8 s) in seasonal competition. The mean playing periods were similar between seasonal and tournament competitions with no clear differences between the two competitions. The mean break duration was 20% (±16%) longer in tournament games than seasonal games. These mean playing and break durations reveal ~1.5 min of work, followed by 1 min of recovery throughout a basketball game.

Differences in the frequency of different offensive demands between seasonal and tournament competition were largely unclear. Seasonal competition showed a substantially higher number of ball reversals (21%, ±25%) and dribble penetration...
(15%, ±17%). Ball reversals and off-ball screens occurred most frequently in both types of competition. The duration of possessions (10%, ±12%) and playing periods (62%, ±48%) increased during the tournament.
Table 4 – Physical, physiological and tactical demands of national season and international tournament competition (mean ± SD).

<table>
<thead>
<tr>
<th>Physical demands (counts•30min⁻¹)⁻¹</th>
<th>Season</th>
<th>Tournament</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total movements</td>
<td>809 ± 80⁻⁰⁰</td>
<td>758 ± 106</td>
</tr>
<tr>
<td>Stand-walk</td>
<td>255 ± 32⁻³⁰⁰</td>
<td>252 ± 34</td>
</tr>
<tr>
<td>Jog</td>
<td>102 ± 23⁻⁰⁰</td>
<td>99 ± 28</td>
</tr>
<tr>
<td>Run</td>
<td>90 ± 17*</td>
<td>82 ± 15</td>
</tr>
<tr>
<td>Sprint</td>
<td>33 ± 7**</td>
<td>28 ± 8</td>
</tr>
<tr>
<td>Low shuffle</td>
<td>94 ± 15**</td>
<td>80 ± 24</td>
</tr>
<tr>
<td>Medium shuffle</td>
<td>193 ± 33*</td>
<td>175 ± 41</td>
</tr>
<tr>
<td>High shuffle</td>
<td>26 ± 9*</td>
<td>24 ± 9</td>
</tr>
<tr>
<td>Jump</td>
<td>19 ± 6⁻⁰⁰</td>
<td>19 ± 5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Physiological demands (min)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Time in zone 1</td>
<td>34 ± 22***</td>
<td>26 ± 28</td>
</tr>
<tr>
<td>Time in zone 2</td>
<td>14 ± 7.0</td>
<td>16 ± 7.1*</td>
</tr>
<tr>
<td>Time in zone 3</td>
<td>8.5 ± 2.8</td>
<td>10 ± 3.8*</td>
</tr>
<tr>
<td>Time in zone 4</td>
<td>17 ± 5.2*</td>
<td>17 ± 5.9</td>
</tr>
<tr>
<td>Time in zone 5</td>
<td>7.1 ± 6.5</td>
<td>6.5 ± 6.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tactical durations (s)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Possession duration</td>
<td>14 ± 3</td>
<td>15 ± 3*</td>
</tr>
<tr>
<td>Rest duration</td>
<td>12 ± 5</td>
<td>14 ± 5*</td>
</tr>
<tr>
<td>Playing duration</td>
<td>96 ± 9</td>
<td>102 ± 9</td>
</tr>
<tr>
<td>Break duration</td>
<td>58 ± 6</td>
<td>65 ± 6*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tactical demands (counts•100possessions⁻¹)</th>
<th>Season</th>
<th>Tournament</th>
</tr>
</thead>
<tbody>
<tr>
<td>Possessions</td>
<td>94 ± 9*</td>
<td>87 ± 10</td>
</tr>
<tr>
<td>Total Elements</td>
<td>248 ± 60</td>
<td>220 ± 36</td>
</tr>
<tr>
<td>Fast breaks</td>
<td>23 ± 3**</td>
<td>20 ± 4</td>
</tr>
<tr>
<td>Ball reversal</td>
<td>87 ± 26**</td>
<td>72 ± 15</td>
</tr>
<tr>
<td>On-ball screen</td>
<td>32 ± 11</td>
<td>28 ± 8</td>
</tr>
<tr>
<td>Dribble penetration</td>
<td>44 ± 7*</td>
<td>37 ± 7</td>
</tr>
<tr>
<td>Hand off</td>
<td>21 ± 7</td>
<td>16 ± 3</td>
</tr>
<tr>
<td>Off-ball screen</td>
<td>57 ± 19</td>
<td>60 ± 25</td>
</tr>
<tr>
<td>Post entry</td>
<td>6 ± 5</td>
<td>7 ± 2</td>
</tr>
</tbody>
</table>

*Counts per 30 min of active playing time.
Superscripts denote clear comparisons of season with tournament games, as follows:
*possibly greater, **likely greater, ***very likely greater, ⁰possibly similar, ⁰⁰likely similar, ⁰⁰⁰very likely similar.
**Discussion**

This is the first research project to compare differences and patterns in the physical, physiological and tactical demands of seasonal and tournament competition in basketball. Overall, seasonal games show a higher intensity in physical demands indicating a faster more stochastic game. Tournament competition entails fewer low intensity movement patterns, but more high intensity movements as the competition progresses. The smaller number of possessions in tournament games is consistent with observations that the international tournament involved a more controlled offensive and defensive style of play. The differing physical and tactical demands between seasonal and tournament competition highlight the need for specific training programs of basketball athletes for the two competition formats. Additionally, strategies limiting the effects of cumulative fatigue on movement patterns in tournament competition need implementing.

The descriptive findings from this research extend previous reports on the physical and physiological demands of male basketball competition. With 24-26 movements per min in seasonal and tournament competition, the total number of movements (~1000) within a game and the frequency of changes in movement every ~2 s are comparable to the movement patterns reported in other male basketball games using standard time-motion analysis (18, 97). These results may underestimate the frequency in change in movement as a more sensitive frame-by-frame time-motion analysis and additional movement categories revealed ~twice the total movement frequencies (138). More high intensity movements in seasonal games likely reflect the advantage of being fresh physically for each single game with minimal cumulative fatigue effects from previous games. These physical demands in seasonal competition indicate the need for basketball athletes and coaches to have a larger focus on frequent high intensity efforts in conditioning practices. Players may need to rely on the anaerobic glycolytic energy system more than in tournament competition and conditioning this metabolic pathway may need to take precedence over aerobic conditioning (28, 66). The other possible explanation for the higher proportion of running and sprinting in seasonal games is the style of play. The higher number of possessions in seasonal games indicates a faster style of game. We consider that international basketball requires a more structured level of defence and offence dictating fewer possessions than seasonal games. We interpret the decrease in the number of low intensity movements (jogging, low to medium intensity shuffling) during tournament competition as indicative of cumulative fatigue.
Conversely, the frequency of high intensity movements (running, sprinting, high intensity shuffling) increased. There are two possible explanations for the increase in high intensity movements in tournament competition. First, as tournament competition progresses into the final stages the quality of the opposition increases which may necessitate more frequent high intensity movements to be successful. Cognitive fatigue may be another factor that results in delayed responsiveness and a need to increase work rates to make up for slower decision making processes. Nonetheless, these findings emphasize the importance of players having the ability to produce high intensity efforts over the length, and especially towards the end, of a tournament. Long-term preparation for tournament competition should incorporate sufficient aerobic and neuromuscular conditioning to minimize fatigue effects and maximize recovery between games. Short-term strategies may include frequent player substitutions during games and post-game recovery interventions such as massage, fluid and macronutrient replenishment, and possibly cold water immersion (104).

The physiological demands measured during seasonal and tournament competition reflect previous findings of peak heart rate values (~95% of HRmax) in junior male players (18), as well as high mean heart rate values (~84% of HRmax) during playing time (18, 94, 97, 139). The heart rate values measured during both seasonal and tournament competition confirm the high physiological demands experienced during basketball games. The greater amount of time spent in Zone 2 (moderate intensity) in tournament competition may reflect short-term fatigue from tournament play (21). Coaches and support staff need to be aware of the magnitude and effects of short-term fatigue from tournament play when planning training and competition strategies. Within a tournament competition the physiological demands correspond with the increase in high intensity movement patterns. An increase in time spent in Zone 4 (high intensity) and mean heart rate over the tournament points towards higher cardiovascular demands as the tournament progresses.

Both seasonal and tournament competition demonstrate mean playing and break periods of ~1.5 and 1 min, respectively. These data indicate the need for basketball athletes to have the metabolic capacity to be highly active for short periods of time (seconds to minutes) and then replenish energy stores within a short rest period. Contemporary practice of Australian basketball athletes involves conditioning towards three min periods (unpublished data, M. Klusemann, Australian Institute of Sport). Our results indicate a one to two min period may be more specific for basketball competition.
The deployment of tactics and strategies presumably has a substantial influence on the outcome of international tournaments. The analysis of tactical demands is rarely available in the public domain. The longer mean duration of possession indicates a different style of play in international tournament competition. This difference presumably reflects a higher level of opposition in international tournaments able to deny early scoring opportunities via more developed team defensive structures. A larger emphasis on more controlled half-court tactics may be more productive in tournament competition. In terms of tactical elements during offence, our analysis reveals that ball reversals, off-ball screens, dribble penetration and on-ball screens were the four most frequently executed elements of an Australian-style offence in both forms of competition. The high number of ball reversals indicates the importance of shifting the ball from one side of the court to the other in order to disrupt the opposition’s defence. The higher frequency of dribble penetration in seasonal competition may be related to a faster style of play allowing players to attack the key area more frequently. Having a focus on dribble penetration could be more conducive to the faster style of seasonal games. Guards are required to dribble more frequently than forwards and centers and should focus on their ball handling and dribble penetration in particular (138, 139).

Future research employing video-based assessment of tactical demands will clarify the offensive and defensive tactics associated with successful teams in both junior and senior competitions.

**Practical applications and conclusions**

The physical preparation for tournament-style play may need to be modified in comparison with that of seasonal competition. Coaches and support staff need to adjust conditioning programs towards the higher movement frequency of seasonal compared to tournament games. Preparing athletes for seasonal competition should involve a larger focus on high intensity interval training to increase the anaerobic capacity of basketball athletes. A work period of ~1.5-2 min with a 1 min recovery for interval-based training would be game-specific in this context. To maintain physical performance in the latter stages of tournament competition, coaches should implement strategies to offset the effects of fatigue. Long-term preparation should develop physical attributes needed to recover from game to game. Conditioning late in the preparation for a major championship needs to bring both endurance and anaerobic qualities to a peak to minimize the effects of fatigue in the latter stages of the tournament. Short-term
strategies may include frequent player substitutions during games and post-game recovery interventions. Our findings indicate that tournament-style play may impose physical demands on basketball athletes that necessitate a change in the style of play related to the challenges of international competition. A more controlled playing style emphasizing half-court tactics involving fewer high intensity movements may be more appropriate for tournament competition. Fatigue management strategies can play a particularly important role in tournament play since better recovery may allow for greater use of faster styles of play against a fatigued defence.

From a tactical standpoint, seasonal competition involves a higher number of possessions than tournaments. Preparation for seasonal competition should have a larger emphasis on the tactical requirements for a faster style of game. Conversely, possessions last longer in tournament competition and highlight the need for structured half-court tactics. Improving skills to perform efficient ball reversals, i.e. passing and leading should have priority in developing elite junior basketball athletes. Further attention should then be given to off-ball screening, on-ball screens and dribble penetration.

Acknowledgments

The authors would like to acknowledge the staff and players of the 2010 Australian Emus team and the AIS basketball program for support and participation in this research project.
Chapter 4
Key performance indicators guide the technical and tactical preparation and development of elite basketball athletes. The following study investigates which factors are most associated with successful rankings in junior and senior, as well as male and female World Championship tournaments.
A cross-sectional analysis of under 17, under 19 and senior male and female FIBA World Championships box score data

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This manuscript is under review at Basketball Research and has been formatted to their requirements.
Abstract

Identifying key performance indicators in international tournament competition allows coaches to better prepare athletes and team tactics. Box score data from competition provides critical performance information for coaches and athletes. **Purpose:** Identify relationships between ranking position and performance indicators, and compare box score data between genders and junior and senior championships. **Methods:** Box score data from the FIBA under 17, under 19 and senior male and female World Championships were collected in the 2010 and 2011 calendar years. A multiple linear regression analysis was used to quantify relationships between ranking position and box score data. Differences between male and female, and senior and junior competition were examined using magnitude-based inferences. Precision of estimation was indicated with 99% confidence limits to accommodate multi-comparisons. **Results:** Offensive indicators (2-point field goals, free-throws made and offensive rebounds) showed very large correlations (R=0.77-0.87, ±~0.2; mean, ±99% confidence limits) with final ranking position in male and senior competition. Defensive and possession indicators (turnovers, defensive rebounds) are related to final ranking position (R=0.80-0.84, ±~0.2) in junior and female competition. Although the number of possessions is similar between male and female basketball competition, 2-point field goal percentages are substantially higher (6%, ±3%) in male championships. Shooting percentages are 3-4% (±4%) higher in senior championships. **Conclusion:** Concentrating efforts on high scoring percentages will increase the likelihood of a successful outcome in senior and male international championships. Applying defensive pressure and reducing turnovers will increase the likelihood of a successful ranking in junior and female FIBA World Championships. Junior players need to focus on improving their offensive scoring abilities to progress to the senior level.

**Keywords:** basketball, international level, key performance indicators, box score data, statistics
Introduction

Coaches, administrators and support staff continually seek ways to better understand factors contributing to success at international basketball competitions. Box score data collected during competition provides useful and critical performance information on the performances of elite players, the level of competitiveness between different nations, and the key indicators that discriminate between successful and unsuccessful teams. This information can guide policy making and management on an administrative level and direct coaches and support staff towards essential areas for player and team development and preparation.

It is well established in the coaching community and research literature that teams with high scoring (field goal percentage) and defensive pressure (defensive rebounds, recovered balls per possession) are successful in seasonal (domestic) basketball competition (53, 169). Season-long success has been attributed to other variables including, assists, steals and blocks (75). While variables such as defensive rebounds and 2-point field goals are important for a single seasonal basketball game, these analyses are restricted to domestic Men’s leagues and not international tournament competition.

The physical and tactical demands of international tournament competition may differ compared to seasonal games. Success in World Championships which are conducted in a tournament-style format may be related to other key performance indicators. Measures of defensive pressure (defensive rebounding, recovered balls per possession) and field goal scoring have discriminated successful teams in the 1999 male junior World Championships (76) and the Beijing Olympics in 2008 (133), but little data exists on current junior or female international competition.

While previous research has mainly focused on senior male competition, little research has investigated female competition (51, 52). Key indicators for success in international female competition and differences compared to male competition remain unclear. Furthermore, key performance indicators of junior (under 17 and under 19) World Championships have not been investigated and would provide useful information on differences between senior and junior international competition run by the International Basketball Federation (FIBA). The information gained from assessing the differences between junior and senior competition can guide national federations in the structuring
and planning of their player development programs. Coaches will also be able to employ specific game strategies and better prepare players for specific competitions.

The aim of this study was to characterise relationships between final team rankings and box score data for junior (under 17 and under 19) and senior male and female FIBA World Championships. A secondary aim was to quantify differences in box score data between senior and junior, and male and female international World Championships.

**Methods**

**Sample and procedures**

Box score data and final ranking positions were made available through FIBA and are accessible online ([http://archive.fiba.com/](http://archive.fiba.com/)). Data from the under 17 and senior FIBA World Championships played in 2010, and the under 19 FIBA World Championships held in 2011 for both females and males was collected. The variables included in the analysis of box score data were: total points made, 2-point field goals, 3-point field goals, free-throws (all attempted, made and percentages), offensive and defensive rebounds, assists, turnovers, steals, blocks and fouls. Box score data is collected by professional FIBA technicians with excellent reliability (133). The data from each competition was pooled into a male group (including under 17, under 19 and senior male competitions, n=24 rankings) and female group (including under 17, under 19 and senior female competition, n=16 rankings) to assess gender-specific effects. The data was also pooled into a junior group (both male and female under 17 and under 19 competitions, n=16 rankings) and senior group (both male and female senior competitions, n=24 rankings) to identify effects within playing levels. To account for game rhythm when interpreting the results, possessions were calculated with the following formula:

\[
\text{Possession} = (2\text{-point field goal attempts} + 3\text{-point field goal attempts}) + 0.5 \times \text{free-throw attempts} - \text{offensive rebounds} + \text{Turnovers} - 4 \ (88).
\]

**Data analysis**

A multiple regression analysis was used to determine the influence of selected box score measures (independent variables) on final ranking position (dependent variable) for both male and female competition, and senior and junior competition. To avoid confounding variables influencing the regression analysis, total points made, shot attempts and percentages, and total rebounds were excluded from the regression analysis (169). The
regression analysis was calculated using PASW statistical package (Version 17.0.1, SPSS Inc, Chicago, IL).

To assess the mean differences between male versus female and senior versus junior competition, a contemporary approach using magnitude-based inferences was employed (11). An unequal variances t-test for independent samples was used to compare group means. Box score data was log-transformed prior to analysis to reduce the non-uniformity of error. Qualitative magnitudes of standardized effects were assessed using the following descriptive scale: trivial < 0.19, small 0.20-0.59, moderate 0.60-1.19, large 1.20-1.99 and very large >2.0 (70). Uncertainty in effects is indicated with 99% confidence limits – this high level of stringency also reduces the probability of type 1 errors emanating from the large number of comparisons. Effects were deemed unclear if the width of the confidence interval simultaneously overlapped the thresholds for small positive and negative effects.

Results

The influence of individual box score variables on final ranking position are summarised in Table 5. In male World Championships, offensive performance indicators (2-point field goals made, free-throws made) had the largest influence on final ranking position. In contrast, female World Championship ranking was determined primarily by indicators of possession (e.g. turnovers, fouls). Success in senior World Championships was also related to offensive performance indicators while defensive markers show stronger correlations in junior competitions. The standard error of the estimate indicates that supremacy in the specific box score variable can predict the final ranking position by ~2-5 places.
Table 5 – Relationship between box score data and final ranking position in FIBA World Championships using a multiple regression analysis (forward method). Correlation coefficients (R) and 99% confidence limits (CL) are shown in descending order with each additional variable contributing to the relationship towards final ranking position in a cumulative manner. The variance related to the correlation is adjusted to the small sample size and is indicated in the second column (Adjusted $R^2$). The Standard Error of the Estimate (SEE) is a measure of the accuracy of prediction and indicates the typical variability (between 2 and 5 positions) in ranking related to that specific variable.

<table>
<thead>
<tr>
<th></th>
<th>R</th>
<th>99% CL</th>
<th>Adjusted $R^2$</th>
<th>SEE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Males</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-points field goals made</td>
<td>0.78</td>
<td>0.46-0.92</td>
<td>0.60</td>
<td>5</td>
</tr>
<tr>
<td>Free-throws made</td>
<td>0.85</td>
<td>0.59-0.95</td>
<td>0.69</td>
<td>4</td>
</tr>
<tr>
<td>Offensive rebounds</td>
<td>0.87</td>
<td>0.64-0.95</td>
<td>0.71</td>
<td>4</td>
</tr>
<tr>
<td>Fouls</td>
<td>0.87</td>
<td>0.65-0.96</td>
<td>0.70</td>
<td>4</td>
</tr>
<tr>
<td><strong>Females</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turnovers</td>
<td>0.80</td>
<td>0.36-0.95</td>
<td>0.61</td>
<td>3</td>
</tr>
<tr>
<td>Fouls</td>
<td>0.86</td>
<td>0.51-0.96</td>
<td>0.69</td>
<td>3</td>
</tr>
<tr>
<td>Steals</td>
<td>0.91</td>
<td>0.67-0.98</td>
<td>0.78</td>
<td>2</td>
</tr>
<tr>
<td>2-points field goals made</td>
<td>0.92</td>
<td>0.70-0.98</td>
<td>0.79</td>
<td>2</td>
</tr>
<tr>
<td><strong>Seniors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-points field goals made</td>
<td>0.71</td>
<td>0.32-0.90</td>
<td>0.49</td>
<td>5</td>
</tr>
<tr>
<td>Offensive rebounds</td>
<td>0.75</td>
<td>0.38-0.91</td>
<td>0.52</td>
<td>5</td>
</tr>
<tr>
<td>Free-throws made</td>
<td>0.77</td>
<td>0.43-0.92</td>
<td>0.53</td>
<td>5</td>
</tr>
<tr>
<td>Steals</td>
<td>0.79</td>
<td>0.24-0.92</td>
<td>0.54</td>
<td>5</td>
</tr>
<tr>
<td><strong>Junior</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Defensive rebounds</td>
<td>0.84</td>
<td>0.47-0.96</td>
<td>0.69</td>
<td>3</td>
</tr>
<tr>
<td>Blocked shots</td>
<td>0.86</td>
<td>0.53-0.97</td>
<td>0.71</td>
<td>3</td>
</tr>
<tr>
<td>Turnovers</td>
<td>0.88</td>
<td>0.57-0.97</td>
<td>0.71</td>
<td>3</td>
</tr>
<tr>
<td>Rebounds offensive</td>
<td>0.91</td>
<td>0.65-0.98</td>
<td>0.75</td>
<td>2</td>
</tr>
</tbody>
</table>

There was no clear difference in the number of possessions per game between male and female competitions. However, 2-point and 3-point field goal percentages are 4-6% (±99% confidence limits, ±3-4%) higher in male championships, resulting in substantially more points scored in male competition. There were 14-20% (±13%) more turnovers and steals in female competition, whereas assists, blocked shots and fouls were more frequent in male competition (Figure 3).
Figure 3 - Comparison of male and female FIBA World Championship box score data. The magnitude of a clear substantial difference is marked with the qualitative descriptors small, moderate or large. All other comparisons were unclear.

The number of possessions was substantially higher (7%, ±3%) in junior compared to senior competition. Despite the higher number of possessions in junior competition, the total amount of points made per game was similar (72 ± 9 points in senior games v 69 ± 10 points in junior games; mean ± SD). Overall shooting percentage was 3-4% (±4%) higher in senior competition. In contrast, there were substantially fewer turnovers, steals and blocked shots in senior competition (Figure 4).
Figure 4– Comparison of junior and senior FIBA World Championship box score data. The magnitude of a clear substantial difference is marked with the qualitative descriptors small, moderate or large. All other comparisons were unclear.

**Discussion**

This study is the first to systematically analyse and examine a full set of box score statistics from the six different FIBA World Championship basketball championships. Box score statistics provide useful key performance indicators to coaches and support staff which can guide training and development of elite basketball athletes. The major finding from this analysis is that final ranking position in World Championship basketball competition is influenced by different key performance indicators depending on gender and age level. Offensive box score measures (2-point field goals) are most strongly related to ranking position in male and senior competition, while indicators of possession (turnovers) and defence (defensive rebounds) are most strongly related to rankings in female and junior competitions, respectively.

The regression analysis reveals that scoring in general and specifically 2-point field goals and free-throws are important indicators for success at a male World Championship. Clearly a basketball athletes’ ability to penetrate towards the basket will increase the likelihood of either 2-point field goal or receiving a foul. These
characteristics have previously been identified as key differentiators between winning and losing teams in male seasonal (domestic) competition (129, 131, 169), although some research has also highlighted the importance of defensive rebounding (50, 53, 156). The importance of players having the athletic ability to penetrate into the key area is consistent with the finding that offensive rebounds are the third most important factor contributing towards final ranking position in international competition. Tall athletic players are essential for meeting these twin offensive requirements of penetration and rebounding. Additionally, coaches should consider employing strategies that increase the likelihood of offensive rebounds by engaging more players in the rebounding contest than their opponent. For example, if an opposition team only commits two players to gaining defensive rebounds, coaches can increase the chances of offensive rebounds by encouraging three players to attack the basket for rebounding opportunities (121).

Interestingly, our analysis suggests that three-point shots made are not a key determinant in influencing final ranking position in male competition. However, this outcome may be misleading in regard to its importance for offensive success. Skilled three-point shooters force the defence to stretch across the court which exposes more opportunities to penetrate into areas closer to the basket, presumably increasing the likelihood of a successful 2-point field goal attempt. A team with fewer expert 3-point shooters may struggle to achieve a high number of 2-point field goals and free-throws. Conversely, our findings indicate that winning a World Championship predominately on three-point shots is unlikely and that a balanced offence with both an inside (2-point) and outside (3-point) game is indicated.

In contrast to male competition, controlling possession appears to be the key determinant in female basketball World Championships. Maintaining control of the ball by minimising turnovers and exerting defensive pressure that leads to steals is crucial for success in female basketball competition. Coaches should employ offensive tactics that enable secure ball movement and alleviate defensive pressure, as well as prescribe defensive tactics that encourages the opposition to turnovers. For example, trapping players or applying full-court defensive tactics should be employed to pressure opposing players. The implications of these tactics on the physical demands of the players need to be taken into account, especially in a tournament style format. The challenge for the coach will be to employ high-pressure tactics without causing detrimental fatigue effects towards the end of a tournament. On an individual level,
these findings highlight the need for female players to apply defensive pressure on their opponent and develop good ball handling and passing skills (43, 51).

A comparison of senior and junior World Championships indicates that key determinants of overall team ranking differ between the levels of competition. While offensive indicators are the largest contributors to final ranking position in senior competition, defensive indicators have a larger influence in junior competition. As defensive rebounds and blocked shots are the key determinants of ranking position in junior basketball competition, coaches need to employ defensive strategies that force contested shots and consequently defensive rebounding opportunities. From a team selection viewpoint, junior coaches need to select tall and/or athletic players who can win defensive rebounding contests and block shots. The findings support the importance of body height as a key determinant of success in elite junior basketball athletes (37).

The importance of controlling possession for female basketball is also highlighted by the comparison with male box score data. While both competitions have a similar number of possessions per game, the 2-point and 3-point shooting percentages are higher in male competitions yielding higher final scores. In contrast, the number of steals and turnovers are higher in female competition. These differences in shooting percentages and ball control can be related in part to a lower level of athleticism of female compared with male athletes (37) which may hinder the females in creating more scoring opportunities. Coaches of female teams need to build well-structured team offensive systems that maximise high percentage scoring opportunities.

The differences in performance indicators between junior and senior competitions highlight specific areas of development for junior basketball athletes. It is clear that senior players have higher shooting percentages and better ball control with fewer steals and turnovers than their junior counterparts. From a development point of view, these differences emphasize the need for junior players to improve their scoring abilities (in all shooting categories) and ball handling abilities (passing/dribbling) to progress to the senior ranks. Coaches will need to carefully balance development of offensive and defensive strategies, coupled with careful selection of players, to improve the chances of success at junior World Championships. Basketball organisations need to reconcile priorities between long-term junior development of scoring abilities, and short-term success at junior World Championships with an emphasis on defensive factors.
Conclusion

Offensive performance appears to be the critical predictor of performance for the male and senior competition, whereas controlling possession predicts success in female competition. Defensive skills and tactics are also important for success in junior World Championships. However, junior players still need to develop scoring skills and ball handling to progress to the senior level. Basketball teams need to incorporate these requirements in their planning of development and competition phases with their junior athletes. The often cited statement among coaches that “offence wins games, but defence wins championships” could now be restated to “offence wins senior and male World Championships, but possession and defence wins junior and female World Championships.”
Chapter 5
Small-sided basketball games are commonly used in training sessions, but the variables that influence the physical, physiological and technical demands of this training tool are not well understood. The following study investigates the influence of the number of players, court size and work-to-rest ratios on the demands of small-sided basketball games and should guide the prescription of competition-specific training.
Optimising technical skills and physical loading in small-sided basketball games

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\textsuperscript{2}Physiology, Australian Institute of Sport, Canberra, Australia  
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Abstract

Differences in physiological, physical and technical demands of small-sided basketball games related to the number of players, court size and work-to-rest ratios are not well characterised. A controlled trial was conducted to compare the influence of number of players (2v2 / 4v4), court size (half / full court) and work-to-rest ratios (4x2.5min / 2x5min) on the demands of small-sided games. Sixteen elite male and female junior players (aged 15-19 years) completed eight variations of a small-sided game in randomised order over a six week period. Heart rate responses and rating of perceived exertion (RPE) were measured to assess the physiological load. Movement patterns and technical elements were assessed by video analysis. There were ~60% more technical elements in 2v2 and ~20% more in half court games. Heart rate (86 ± 4% & 83 ± 5% of maximum; mean ± SD) and RPE (8 ± 2 & 6 ± 2; scale 1-10) were moderately higher in 2v2 than 4v4 small-sided games, respectively. The 2v2 format elicited substantially more sprints (36%, ±12%; mean, ±90% confidence limits) and high intensity shuffling (75%, ±17%) than 4v4. Full court games required substantially more jogging (9%, ±6%) compared to half court games. Fewer players in small-sided basketball games substantially increases the technical, physiological and physical demands.

Keywords: sport-specific conditioning, games-based training, basketball practice, basketball drills, basketball training
Introduction

Over the last decade, a new approach to improving team-sport athletes’ fitness has been developed in the form of game-based conditioning. The purported benefits of game-based conditioning include greater transfer of physiological adaptations when the exercise simulates sports-specific movement patterns (6), athletes simultaneously develop technical and tactical skills under high physical loads (47), and higher motivation of athletes performing sport-specific rather than traditional conditioning (146). Sport-specific conditioning in the form of small-sided games has been evaluated extensively in team sports such as football (61), rugby (44, 48, 49), handball (23), but less so in basketball (27, 128). The small number of research studies on basketball training is surprising given the almost universal use of small-sided games in both junior and senior programs. Sport-specific conditioning can provide a similar or perhaps greater increase in physical fitness than traditional conditioning drills (47, 61, 146).

Game-based conditioning can elicit improvements in performance in competition through improvements in skill execution (44, 47). Given the likely benefits of small-sided games in basketball practice in improving both skills and conditioning, it is important to characterise (under controlled conditions) variables of training prescription that influence the relative contributions of the physical (movement patterns), physiological (cardiovascular), and technical (skill repetition) demands of various small-sided basketball games. The organisational pattern of small-sided basketball games defines the balance between physical and physiological demands and technical practice needed for competitive success.

Several factors that influence the physiological, physical and technical demands of small-sided games and thus the desired training stimulus from game-based conditioning have been identified in football (61). Variables such as number of players, field dimensions and work-to-rest ratios will determine the physical, physiological and technical demands and thus training adaptations from small-sided games. Increasing the number of players decreases the number of technical actions per player, while field dimensions have less of an effect on the total technical demands in small-sided football games (35, 82, 115). Identifying the influence of different variables on the technical demands of small-sided basketball games would allow coaches to better plan and implement skill-based training programs. Decreasing the number of players while keeping the relative playing area constant increases the physiological and physical intensity of a small-sided football game (35, 60, 62, 81, 85, 120, 165). A decrease in
team size on a full basketball court, thus increasing the relative court area, has also been shown to increase physiological demands (27). This indicates that smaller team sizes would increase physiological and perhaps also physical demands of small-sided basketball games. An increase in playing area generally induces larger physiological responses in small-sided football games (120). Full court basketball practice games have higher physiological and physical demands than half court 5on5 scrimmages (102), suggesting that a larger court area would increase physiological and physical demands in small-sided basketball games.

Another factor to consider is the effect of intermittent and/or continuous small-sided games. High intensity movement patterns occur longer and more frequently in intermittent small-sided football games, where as heart rate and perceived exertion responses are higher in continuous formats (63). The impact of different work-to-rest ratios in small-sided basketball games remains unknown and this knowledge is crucial for employing game-based conditioning drills in practice. In basketball, most drills and small-sided games are conducted in either half of the court, or the full court with one to five players on a team, and a duration of approximately 5-10 min (102). Understanding the influence of training variables on the physiological, physical and technical demands of small-sided games in basketball should allow coaches and sport scientists to better prescribe and implement sport-specific training programs.

The aim of this study was to quantify the magnitudes of difference in physical, physiological and technical demands in various types of small-sided basketball games to assess the influence of number of players (2v2 versus 4v4), court size (half versus full) and work-to-rest ratio (4x2.5 min vs. 2x5 min). The existing research on small-sided games, particularly in football, is informative but basketball-specific research is needed to clarify important questions for basketball coaches, researchers and strength and conditioning staff.

Methods

Experimental Approach
A controlled experimental trial was conducted to assess the physiological, physical and technical demands of small-sided games. The combination of player number (two players per team – 2v2 or four players per team – 4v4), court size (half or full court) and work-to-rest ratio (4x2.5 min or 2x5 min) resulted in eight variations of small-sided games. Small-sided games using the half-court size were created by incorporating a
second basketball hoop, 3-point line and keyway at the halfway line. Creating a half-court game in this manner was necessary to ensure the entire half-court area (15 x 14 m) was used and rules were consistent between half-court and full-court games. The 4x2.5 min games were divided into four 2.5 min quarters with a one minute rest interval between each quarter. The 2x5 min small-sided games involved two five minute halves with a 30 second rest at half time which allowed teams to switch sides. The experimental design involved the participants playing each small-sided game in a randomised order. The small-sided games were scheduled over a six week period during the pre-season.

Participants
Sixteen elite junior basketball players were recruited from the Australian Institute of Sport (AIS) Men’s and Women’s basketball program (eight male; age 18.2 ± 0.3 y, height 1.92 ± 0.06 m, mass 87 ± 4 kg; mean ± SD, - eight female; age 17.4 ± 0.7 y, height 1.86 ± 0.09 m, mass 80 ± 16 kg). All participants and guardians gave informed consent and ethics approval was obtained from the Australian Institute of Sport’s Ethics Committee, approval number 20100402. Due to injury or illness six of the athletes were not able to compete in all versions of small-sided games. In these cases, other squad members of the same position were used as replacements. Comparisons were only made between game variations that were played by the same basketball player.

Procedures
Each of the eight variations of a small-sided game was conducted at the beginning of a regular training, following a standardised five minute warm up. The male and female participants were divided into two groups of four which competed against each other in a tournament style format. Each group undertook one of the games during each session. The same pair or quad grouping of players was used throughout the study of 19 games. The teams were controlled for positional balance by including one or two perimeter and post players each in 2v2 or 4v4 games, respectively. Due to a shortage in player numbers, five 2v2 games were only played once. Scores were recorded and an incentive (movie tickets) offered to the group with the most wins at the end of the study period. Verbal encouragement was given by the research and coaching staff during the games. No technical or tactical aspects of basketball were emphasised or coached to avoid influencing the athletes’ style of play. Minor rule modifications including a 12 second shot-clock and rewarding a point when being fouled in shooting motion to exclude foul shots, were incorporated to allow for continuous play. Pilot testing indicated that a 24
second shot-clock (in a half-court setting with fewer players) was too long to invoke high physical and physiological demands necessary for conditioning purposes.

The physiological, physical and technical demands of each game were quantified through heart rate monitoring, sessional rating of perceived exertion (RPE) taken one min after the end of the game, movement pattern analysis and video coding. Heart rate profiles were captured through a commercially available telemetry heart rate system (Suunto™, Vantaa, Finland). Values were expressed as mean and peak heart rate as a percentage of each subject’s individual maximum heart rate (HRmax), percentage of time spent in Zone 4 (80-89 % of HRmax), and Zone 5 (90-100 % of HRmax). HRmax was determined through the Yo-Yo Intermittent Recovery Test Level 1 which was undertaken one month prior to the study. Movement patterns and technical elements were obtained from notational video analysis using sports coding software (SportsCode Elite, Sydney, Australia). The events coded for movement patterns were stand/walk, jog, run, sprint, low, medium and high intensity shuffle and jumps (18, 97) and expressed as movement counts. In brief, jogging was defined as forward movement involving a flight phase without urgency, while running involved moderate urgency and a more pronounced arm swing. Sprinting efforts were forward movements with high to maximal intensity. Shuffling was defined as any sideways or backwards movement from low to high intensity. Technical demands were coded as dribbling, passing, mid-range shots (shots outside key area, within 3-point line), 3-point shots (shots outside 3-point line), close range shots (shots within key area), rebounding and ball-screens. The technical demand of each small-sided game was indicated by the frequency of each of the technical elements. Estimating the frequency of movement patterns has good reliability with a coefficient of variation of 2-4% (18). Test-retest reliability of the frequency of technical elements was deemed acceptable with an intraclass correlation of 0.99 and typical error of 4%.

Statistical Analysis

Technical, physical and physiological data of each player was collated into an MS Excel database. Gender as a covariate had no clear effect on the dependent variables. The data from the male and female participants was thus pooled and analysed together. All measures were log-transformed prior to analysis to reduce the non-uniformity of error (5). Comparisons between the small-sided game variables (number of players, court size and work-to-rest ratio) were made by estimating the magnitude of difference of each variable between games. Standardised changes and differences (effect sizes) were
calculated with precision of estimation indicated by 90% confidence limits (71). An effect was inferred to be unclear if its confidence interval spanned substantial positive and substantial negative values. Clear effects were expressed as substantial and described qualitatively with the following descriptors: trivial \(< 0.2\), small 0.2-0.6, moderate 0.6-1.2, large 1.2-2.0 and very large \(> 2.0\) (70). Test-retest reliability for the technical and physical demands was calculated with the typical error of measurement and intraclass correlation coefficient.

**Results**

*Technical demands*

The number of players per team had the largest effect on all technical elements. The total number of technical elements per player was substantially higher (~60%) in 2v2 games (Figure 5) compared to 4v4 games. The number of close range shots performed was ~three fold higher in 2v2 small-sided games. The number of dribbles, passes, rebounds and on-ball screens were moderately higher in 2v2 games. Similarly, the number of mid-range jump shots and 3-point shots were higher in 2v2 games (Table 6). The quadrants outlined in Figure 5 show that 2v2 games elicited \(\geq\) five technical elements per min.

Court size was less influential on the technical demands. Half court games elicited ~20% more total technical elements and passing than full court games. Except for ball-screens, the number of all other technical elements was substantially higher in half court games. The work-to-rest ratio had a small effect on the overall technical demands with 4, ±2 (difference in means, ±90% confidence limits) more technical elements in 4x2.5 min type games. There were no substantial differences in the number of individual technical elements between 4x2.5 min or 2x5 min small-sided games. The coefficient of variation for the total number of technical elements from game to game across all combinations of the small-sided games was 34%.
Figure 5 - Comparison of technical elements per min for 2v2 and 4v4, full court and half court games. Subject gender and 2x5 min and 4x2.5 min work-to-rest ratios indicated on x-axis. Bars indicate mean ± SD.

Figure 6 - Comparison of rate of perceived exertion (RPE) responses to 2v2 and 4v4, full court and half court games. RPE values were substantially higher for full court and 2v2 small-sided games. Bars indicate mean ± SD.
Table 6 - Magnitude of difference (effect size, ±90% confidence limits) in number of technical elements between different variables of small-sided games. *substantial difference

<table>
<thead>
<tr>
<th>Technical element (per player per game)</th>
<th>Player number (4v4 ; 2v2)</th>
<th>Court size (Half ; Full)</th>
<th>Work-to-rest ratio (2x5 min ; 4x2.5 min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean ± SD</td>
<td>Effect size, ±CL</td>
<td>mean ± SD</td>
</tr>
<tr>
<td>Total elements</td>
<td>43 ± 10 ; 68 ± 12</td>
<td>2.28, ±0.30* very large</td>
<td>57 ± 18 ; 46 ± 13</td>
</tr>
<tr>
<td>Dribble</td>
<td>12 ± 5 ; 20 ± 6</td>
<td>1.18, ±0.27* moderate</td>
<td>16 ± 8 ; 13 ± 6</td>
</tr>
<tr>
<td>Pass</td>
<td>15 ± 5 ; 19 ± 5</td>
<td>0.94, ±0.31* moderate</td>
<td>18 ± 6 ; 14 ± 4</td>
</tr>
<tr>
<td>Close range shot</td>
<td>3 ± 2 ; 8 ± 3</td>
<td>1.71, ±0.37* large</td>
<td>6 ± 4 ; 5 ± 3</td>
</tr>
<tr>
<td>Mid-range jump shot</td>
<td>2 ± 2 ; 4 ± 3</td>
<td>0.44, ±0.33* small</td>
<td>3 ± 3 ; 2 ± 2</td>
</tr>
<tr>
<td>3-point shot</td>
<td>2 ± 2 ; 3 ± 3</td>
<td>0.37, ±0.36* small</td>
<td>3 ± 3 ; 2 ± 2</td>
</tr>
<tr>
<td>Rebound</td>
<td>5 ± 3 ; 8 ± 3</td>
<td>1.18, ±0.38* moderate</td>
<td>7 ± 2 ; 5 ± 3</td>
</tr>
<tr>
<td>On-ball screen</td>
<td>3 ± 3 ; 5 ± 4</td>
<td>1.17, ±0.44* moderate</td>
<td>4 ± 4 ; 4 ± 5</td>
</tr>
</tbody>
</table>
Physiological demands

The number of players had the largest influence on RPE scores (Figure 6). RPE scores (scaled 1-10) were moderately higher by two units in 2v2 games compared to 4v4 games. Mean heart rate was also substantially higher in 2v2 games by ~3, ±1 beats per min (difference in mean, 90% confidence limits). Court size had a moderate effect on RPE with full court games eliciting higher RPE ratings than half-court games. No clear substantial differences were seen in any of the heart rate variables for court size (Table 7). Mean heart rate was moderately higher in 2x5 min small-sided games compared to 4x2.5 min types. RPE was substantially higher and the amount of time spent at >90% of maximum heart rate was two-fold longer in 2x5 min small-sided games. Conversely, time spent with a heart rate in the range of 80-89% of maximum heart rate was substantially longer in the small-sided games with 4x2.5 min work-to-rest ratios.

Physical demands

The number of players, court size and work-to-rest ratio had variable impacts on specific movement patterns in small-sided games (Table 8). The number of players has the largest influence on high intensity exercise with 2v2 games involving higher frequencies of sprints (36%, ±12%; mean, ±90% confidence limits), high intensity shuffling movements (75%, ±17%) and jumps (69%, ±9%). Court size also had the largest influence on low to moderate intensity movement patterns and the total number of movements. Half court games included 25% more standing and walking, and more low (32%, ±9%), medium (26%, ±10%) and high (40%, ±19%) intensity shuffling type movement patterns than full court games. Full court games involved a similar number of sprints but substantially more jogging movements (9%, ±6%). The total number of movements is 17% higher in half-court games and 7% higher with 4x2.5 min work-to-rest ratios compared to 2x5 min small-sided games. The 4x2.5 min type small-sided games had substantially higher frequencies of moderate to high intensity movement patterns with small to moderate differences in running, sprinting, jumping, medium and high intensity shuffling.

The relationship between the technical and physiological demands is illustrated in Figure 7. All 2v2 games elicited higher RPE responses and technical elements than 4v4 games. Full-court 4v4 games with longer playing periods can produce similar physiological demands to 2v2 games, but involve fewer individual technical elements.
Table 7 – Magnitude of difference in RPE and heart rate data (effect size, ±90% confidence limits; qualitative descriptor) between different variables of small-sided games. *substantial difference

<table>
<thead>
<tr>
<th>Physiological demand</th>
<th>Player number (4v4 ; 2v2)</th>
<th>Court size (Half ; Full)</th>
<th>Work-to-rest ratio (2x5 min ; 4x2.5 min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Effect size, ±CL</td>
<td>Mean ± SD</td>
</tr>
<tr>
<td>RPE</td>
<td>6 ± 2 ; 8 ± 2</td>
<td>0.95, ±0.26* moderate</td>
<td>6 ± 2 ; 7 ± 2</td>
</tr>
<tr>
<td>Peak heart rate as % of max heart rate</td>
<td>92 ± 3 ; 92 ± 3</td>
<td>0.28, ±0.29* small</td>
<td>92 ± 3 ; 92 ± 3</td>
</tr>
<tr>
<td>Mean heart rate as % of max heart rate</td>
<td>83 ± 5 ; 86 ± 4</td>
<td>0.53, ±0.26* moderate</td>
<td>84 ± 5 ; 85 ± 4</td>
</tr>
<tr>
<td>Mean % time spent in Zone 4 (80-89% HR max)</td>
<td>51 ± 20 ; 55 ± 24</td>
<td>0.10, ±0.40 unclear</td>
<td>46 ± 27 ; 56 ± 19</td>
</tr>
<tr>
<td>Mean % time spent in Zone 5 (90-100% HR max)</td>
<td>22 ± 25 ; 30 ± 31</td>
<td>0.10, ±0.33 unclear</td>
<td>20 ± 27 ; 25 ± 27</td>
</tr>
</tbody>
</table>
Table 8 – Magnitude of difference in frequency (count) in movement patterns (effect size, ±90% confidence limits; qualitative descriptor) between different variables of small-sided games. *substantial difference

<table>
<thead>
<tr>
<th>Physical demand (count)</th>
<th>Player number (4v4 ; 2v2)</th>
<th>Court size (Half ; Full)</th>
<th>Work-to-rest ratio (2x5 min ; 4x2.5 min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean ± SD</td>
<td>Effect size, ±CL</td>
<td>mean ± SD</td>
</tr>
<tr>
<td>Total Movements</td>
<td>378 ± 51 ; 382 ± 52</td>
<td>0.07, ±0.18 trivial</td>
<td>407 ± 30 ; 340 ± 35</td>
</tr>
<tr>
<td>Stand/Walk</td>
<td>125 ± 23 ; 120 ± 18</td>
<td>-0.20, ±0.17* small</td>
<td>137 ± 14 ; 103 ± 11</td>
</tr>
<tr>
<td>Jog</td>
<td>66 ± 12 ; 63 ± 11</td>
<td>-0.28, ±0.25* small</td>
<td>63 ± 13 ; 68 ± 10</td>
</tr>
<tr>
<td>Run</td>
<td>35 ± 10 ; 35 ± 10</td>
<td>0.06, ±0.33 unclear</td>
<td>34 ± 9 ; 37 ± 11</td>
</tr>
<tr>
<td>Sprint</td>
<td>11 ± 5 ; 15 ± 5</td>
<td>0.73, ±0.26* moderate</td>
<td>13 ± 6 ; 13 ± 6</td>
</tr>
<tr>
<td>Low shuffle</td>
<td>42 ± 10 ; 39 ± 12</td>
<td>-0.39, ±0.28* small</td>
<td>45 ± 9 ; 32 ± 9</td>
</tr>
<tr>
<td>Med shuffle</td>
<td>75 ± 17 ; 72 ± 19</td>
<td>-0.19, ±0.24* trivial</td>
<td>81 ± 13 ; 62 ± 20</td>
</tr>
<tr>
<td>High shuffle</td>
<td>8 ± 4 ; 13 ± 6</td>
<td>0.97, ±0.28* moderate</td>
<td>11 ± 5 ; 7 ± 3</td>
</tr>
<tr>
<td>Jump</td>
<td>16 ± 6 ; 26 ± 5</td>
<td>1.75, ±0.29* large</td>
<td>23 ± 8 ; 18 ± 6</td>
</tr>
</tbody>
</table>
Discussion

The results from this study allow a better understanding of the effect of different variables on the technical, physiological and physical demands of small-sided games using a 12 second shot-clock. This is the first study to systematically investigate the effect of the number of players, court size and work-to-rest ratios on the various demands of small-sided basketball games. The main finding is that the number of players has the largest influence on the technical, physiological and high intensity movement patterns in small-sided basketball games. While the general findings are consistent with other reports on small-sided games (Hill-Haas et al. 2011), the specific details of the technical, physiological and physical demands of basketball small-sided games should provide useful information for basketball coaches and support staff. The primary outcome here is that the number of players in small-sided basketball games is the key factor influencing physical and technical demands.

Technical demands

The number of players had the largest influence on the technical demands with 2v2 games involving ~60% more technical executions than 4v4 games. This finding was not surprising as the smaller number of players in a team allows for more “ball touches” and hence skill executions per player. A similar finding of more touches with fewer players has been reported in small-sided football games (80, 115, 116). Especially close range shots were performed more frequently in 2v2 games. This finding supports the use of 2v2 games for incorporating a higher number of repetitions of close range shots which
are a key performance indicator in differentiating winning from losing teams (34, 133, 156, 158).

While decreasing the number of players and thus increasing the amount of ball touches would be beneficial for individual skill development, the addition of players shows an increase in the total number of technical actions performed overall (115). The value of involving a larger number of players in small-sided games therefore lies in enhancing team-specific decision making skills - more team members and opposition players are involved in the decision making processes. Additionally, technical demands executed without the ball such as cutting, off-ball screening, maintaining spacing, sealing, and leading were not coded. Assessing the frequency of these technical elements may distinguish the technical demands of 2v2 and 4v4 small-sided games. It is likely that technical elements executed without the ball occur more frequently in 4v4 games than 2v2 games.

Defensive skill elements of basketball were not tracked in the small-sided games, but can be associated with the corresponding offensive elements. For example, the fact that on-ball screens occurred more frequently in 2v2 games means that on-ball screen defence would correspondingly occur more often in these games too. To further maximise the frequency of technical elements, half-court games should be implemented over full-court games. In particular there are substantially more passes in the half-court variant. The higher technical demands in half-court games are due to shorter durations of possession, allowing more possessions and thus more technical elements or touches per game. The higher frequency of possessions with smaller playing surface sizes has also been reported in football with more shots occurring on smaller pitch sizes (82). Future research should incorporate other aspects of technical demands, such as offensive and defensive technical elements executed without the ball, in sport-specific small-sided games.

**Physiological and physical demands**

When designing small-sided games from a conditioning point of view, choosing the number of players per team seems to have the largest influence on the physiological demands and high intensity movement patterns. Using fewer players in a team increases the relative court area per player forcing players to be more involved in game play. These adjustments increase the physiological demands and high intensity movement patterns. Similar responses have been reported in basketball (27, 128) and football small-sided games (61, 85, 120). Mean heart rate in 2v2 games was lower compared to
previously reported findings in regional level Italian male basketball players (86 ± 4% versus 92 ± 6% of estimated maximal heart rate) (27), but comparable to 3v3 games in younger basketball athletes (87 ± 4%) (128). These differences in heart rate responses may be due to including the rest periods in our calculation of mean heart rate and/or higher fitness levels in our national level participants. Interestingly, RPE results from our 2v2 games (8 ± 2; mean ± SD) are similar to those (7 ± 2) reported by Castagna et al. (2011) indicating a relatively consistent psycho-physiological response.

The perceived demand of a small-sided game is also moderately higher in the full court. The higher RPE scores (7-8 ± 2 vs. 3 ± 1) from our study and previous findings (27) on 2v2 small-sided games compared to 3v3 small-sided games presumably relates to the small court size (12m²) used in the research project by Sampaio et al. (2009). A higher RPE can be attributed to the higher frequency of moderate intensity exercise at the cost of low intensity exercise. However, half-court small-sided games elicit more shuffling type movements and changes in movement patterns which reflect the movement characteristics of basketball competition (18, 79, 94, 97).

Intermittent work-to-rest ratios (4x2.5 min + one min rest period) induce more moderate to high intensity movement patterns, and a more frequent change in movement patterns compared to 2x5min small-sided games. Half court 4x2.5min type small-sided games would therefore suit conditioning basketball athletes to specific movement demands of basketball games. Full court 2x5min small-sided games have higher cardiovascular demands and are more likely to elicit improvements in aerobic fitness.

Understanding the influence of different small-sided games on the physiological and physical demands allows coaches to design specific basketball conditioning games according to specific conditioning goals. Full court, 2v2 2x5 min small-sided basketball games have the highest cardiovascular demand and induce physiological responses required for aerobic adaptations. Half-court, 4x2.5 min small-sided basketball games elicit more moderate to high intensity shuffling type movement patterns and changes in movement that replicate a majority of specific competition demands. Coaches should explore possibilities with the 12 second shot-clock in small-sided games to ensure physical and physiological loads are high enough to promote improvements in conditioning.

The findings from this research can help coaches and support staff plan and program their training sessions to meet specific technical and conditioning goals. It is now clear
that 2v2 small-sided games involve the highest technical and physiological demands. Manipulating court size and work-to-rest ratio influences the balance between technical and physiological/physical demands. An improved understanding of how to modify the demands of small-sided basketball games will assist coaches to prescribe more effective training loads and periodised training programs. Further research in game-based conditioning basketball drills is needed to clarify the effects of different variations (e.g. 1v1 and 3v3) of small-sided games that influence technical, physiological and physical demands.

**Conclusion**

The number of players on court has the largest effect on physiological and technical demands in small-sided basketball games. Court size and work-to-rest ratios can also influence the frequency of various movement patterns. Basketball coaches can manipulate different variables of small-sided games to establish the technical, physiological and physical demands of their basketball practice. When planning game-based drills with a small number of players (e.g. 2v2), the frequency of technical elements and thus skill repetition in these games will be high. The effect on the physical and physiological load of 2v2 must also be considered. The physical and physiological demands of 2v2 small-sided basketball games are substantially higher than 4v4 games. Game-based basketball drills that have intermittent type profiles (whether this is planned or arises from frequent stoppages for coaching instructions) will have more changes in movement and higher intensity movement patterns. Full court, 2x5min games will create more low to moderate intensity movements and higher cardiovascular demands. Applying these training concepts will help coaching staff meet specific training and conditioning goals.

**Acknowledgements:**

The authors thank the coaches and players of the Australian Institute of Sport Men’s and Women’s Basketball programs for their participation and commitment to this research project.
Chapter 6
Scoring has been identified as a key skill in basketball. Successful shooting determines the amount of scoring an individual and team can achieve. Three-point shooting is an especially difficult skill that provides the advantage of scoring more points for a single possession and requires more effort from the opposition to defend. Coaches and sport scientists continually seek novel ways of improving the shooting abilities of elite basketball athletes. The following study aims at improving three-point shooting in elite female basketball athletes.
Video-based training combined with flotation tank recovery does not improve three-point shooting in basketball

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\textsuperscript{2}School of Human Movement Studies, Charles Sturt University
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Abstract

Purpose: Video-based training combined with flotation tank recovery may provide an additional stimulus for improving shooting in basketball. Methods: A pre-post controlled trial was conducted to assess the effectiveness of a 3 week intervention combining video-based training and flotation tank recovery on three-point shooting performance in elite female basketball athletes. Players were assigned to an experimental (n=10) and control group (n=9). A three week intervention consisted of 2 x 30 min float sessions per week which included 10 min of video-based training footage, followed by a three week retention phase. A total of 100 three-point shots were taken from five designated positions on the court at each week to assess three-point shooting performance. Results: There was no clear difference in the mean change in the number of successful three-point shots between the groups (-3%, ±18%; mean, ±90% confidence limits). Conclusion: Video-based training combined with flotation recovery had little effect on three-point shooting performance.

Keywords: basketball shooting, restricted environmental stimulation therapy (REST), float tank recovery, visual training
Introduction

Performance indicators such as number of total rebounds and successful shot attempts differentiate successful teams from lower ranked teams in basketball (34, 51, 53). Improving the players’ shooting ability is imperative to successful basketball performance. Three-point shooting is a comparatively difficult task as it requires the player to score from a long distance behind the “three-point” line (6.75 m from the basket under FIBA regulations). The increased risk of shooting from behind the three-point line is rewarded with one extra point compared to shots within the three-point line. Highly skilled male and female players can achieve a three-point shooting percentage of up to 50% in competition (77), making this shot a viable tactical option. Elite players with high three-point shooting percentages are often specialists in the craft of shooting and employed for this specific skill.

The ability to identify key elements that lead to successful shooting has been the focus of previous research. The kinematics of shooting have been investigated for jump shots (73, 98, 100), free-throw shooting (59, 137, 152) and three-point shots (40). Successful shooting is associated with a straight and high ball release, and forearm position and wrist flexion are critical for consistent straight projection of the ball with backspin (118, 151). Release angles ranging from 50-60° above the horizontal plane are required for optimal shooting accuracy (73, 84, 100). With increasing shooting distance these shooting kinematics need to be adjusted (90, 100). Skilled movement coordination and adaptation is required to fulfil these criteria for optimal shooting accuracy during gameplay. Thus, any intervention that enhances shooting movement patterns and increases shooting accuracy can have a substantial impact on basketball performance.

Flotation tank recovery, also known as flotation restricted environmental stimulation therapy (REST), involves an individual lying supine in a dark, sound-reducing tank containing a saline solution, effectively increasing the density of the water which allows the person to float. This form of therapy has been previously used as a relaxation tool for stress-management (161) and to increase internal focus and primary-process orientation important for complex skill execution (109). Several investigations have reported positive benefits on sports performance following single (9, 148, 149) or multiple (89, 96, 164) exposures of flotation tank recovery, usually combined with imagery training. Of these studies, one has reported benefits in basketball shooting (37% improvement in free-throw basketball shooting) after flotation tank recovery combined with imagery training in novice players (148). The effect of flotation tank
recovery on other forms of shooting such as the three-point shot or in more experienced basketball athletes remains unknown.

Another form of intervention to enhance sports performance is the use of relaxation and visual-imagery techniques, Visuo-Motor Behaviour Rehearsal (150), combined with displaying video footage of a role model performing the desired skill. Visuo-Motor Behaviour Rehearsal combined with a video-recorded role model has been shown to improve free-throw shooting in collegiate-level female (55, 58) and male basketball athletes (113). Observing a video-recorded model on its own has also been effective in enhancing free-throw shooting in higher skilled male basketball athletes (113). Whether a similar type of intervention using self-as-a-model feedback combined with an optimal role model is effective for other forms of basketball shooting remains unclear.

In theory, there may be benefits from flotation tank recovery which can increase internal focus and primary-process orientation through a reduction in external stimuli, combined with video-based training for three-point basketball shooting in elite level players. No previous research has examined the effectiveness of this combined approach in basketball shooting. The aim of this study was to assess whether the combination of video-based training with flotation tank recovery improves three-point shooting performance in elite female basketball athletes. This intervention may increase the three-point shooting success rate of individual players, and a team’s overall performance as a whole.

**Methods**

A longitudinal controlled experimental trial was conducted to quantify the effectiveness of video-based training combined with flotation tank recovery compared to regular basketball training on three-point shooting. Both an experimental and control group performed weekly three-point shooting tests every Thursday afternoon for seven weeks. After the first baseline test, the experimental group had two 30 min video Float sessions per week on non-consecutive days (Monday and Wednesday) for three weeks. Following this intervention phase, the weekly shooting tests continued in order to quantify the degree of retention or delayed effects. The control group did not participate in any form of video-based training or flotation tank recovery. The study was conducted during the beginning of the Australian-based Women’s National Basketball League (WNBL) season (October-December). This study design was chosen to analyse an important aspect of sports performance (three-point shooting) in a controlled
experimental setting. Analysing shooting performances directly from competition would include too many uncontrollable confounding variables. The outcomes of this research design will help determine whether this type of intervention can have a direct impact on sports performance.

**Participants**

Elite female basketball athletes were recruited from two WNBL teams. The Canberra Capitals is a professional club that includes national squad members (n=10, age: 25 ± 4 y, height: 1.81 ± 0.09 m; mean ± SD). The Australian Institute of Sport (AIS) Women’s Basketball program is an elite junior development program that consists of Australia’s most talented junior basketball athletes (n=9, age: 18 ± 1 y, height: 1.83 ± 0.09 m). All players had several years of basketball training, but no experience in flotation-tank recovery or video-based training. To provide homogenous groups, six players from the Canberra Capitals and four players from the AIS Women’s Basketball program were assigned to the experimental group (n=10; comprising 4 guards, 4 forwards, and 2 centres, age: 23 ± 5 y, height: 1.82 ± 0.09 m). The control group consisted of four players from the Canberra Capitals and five players from the AIS Basketball program (n=9; 4 guards, 3 forwards, and 2 centres, age: 20 ± 4 y, height: 1.82 ± 0.08 m). Written informed consent was collected from all participants and their guardians. The research project was approved by the Australian Institute of Sport Ethics Committee, approval number 20111004.

**Measures**

Players completed a total of 100 three-point attempts once per week to assess their three-point shooting ability. The three-point shooting test consisted of two sets of 50 three-point shots taken from five specific locations on the court (2 x corners, 2 x wings and top). The players had four attempts from each location starting in the right corner, and then repeated the sequence twice with three attempts per location. Players were handed the ball directly by one of the investigators for each shot attempt. Every successful and unsuccessful shot was recorded manually on a score sheet. A one min rest was given between the two sets of shooting to avoid fatigue affecting shooting performance. The number of successful shots out of 100, as well as for the first and second 50 shots were used as measures of shooting performance. No time constraint was placed upon the players, however they were encouraged to shoot immediately after receiving the ball. The mean duration of the test was 5:08 ± 0:14 min (± SD) excluding
the one min rest between the first and second 50 shots. Players completed the shooting test each week at their respective team’s training location.

At the conclusion of the study, each player completed a questionnaire including 14 items with a six-point Likert scale (Strongly Disagree to Strongly Agree) referring to the usefulness of the study overall for three-point shooting, the effectiveness of weekly three-point shooting tests, and their perception of the usefulness of the video-based flotation tank recovery intervention on three-point shooting.

**Procedures**

Players in the experimental group participated in two 30 min flotation tank recovery sessions per week on non-consecutive days. Flotation tank recovery involved the players lying supine in a light-proof tank with a ~30 cm deep saline solution (Epsom salts) warmed to ~35 °C. Ear plugs and an air cushion were provided for comfort and neck support. At the beginning of each session, players watched approximately 10 min of video footage via a video monitor located in the tank directly above the participant. The video included a short (~5 min) technique segment highlighting aspects of the player’s shooting technique in need of improvement. Individualised written cues (key words or phrases) from the respective team coaches were overlaid on front and side-on footage of the player shooting. To demonstrate the correct execution and highlight the cues, footage of role model performances with world-class shooting techniques from competition footage (2008 Beijing Olympics, WNBA 2011 Playoffs, FIBA World Championships 2010) was shown (~5 min). Two written and individualised coaching cues were provided for each player. To allow the players to focus on one cue at a time, both coaching cues were presented separately on the video in the first two weeks and then shown together in the third week. The video footage did not contain any audio to reduce any disruption to the flotation tank recovery.

**Analysis**

All data were analysed descriptively with mean and standard deviation. Magnitude-based inferences were employed to assess the change in three-point shooting performance within and between the groups. All data were log-transformed prior to analysis to reduce non-uniformity of error or effects (71). Precision of estimates are indicated with 90% confidence limits. Effects with confidence limits overlapping the threshold for small positive and negative effects were defined as ‘unclear’. Clear effect sizes were defined as ‘substantial’. Effect sizes were interpreted as follows: trivial <
0.19, small 0.20-0.59, moderate 0.60-1.19, large 1.20-1.99 and very large >2.00. The control group had a substantially lower baseline score compared to the experimental group. Baseline scores were therefore used as a covariate to adjust for this difference. Reliability of the shooting test was calculated from the control group’s first and second shooting tests which revealed a typical error of 5 successful shots per 100 attempts (coefficient of variation 17%) with an intraclass correlation of 0.89.

**Results**

There was no clear difference in the mean improvement between the experimental and control groups in successful three-point shots directly after the intervention (-2%, ±23%; mean, ±90% confidence limits), or following the three week period post-intervention (-3%, ±18%). The experimental group had a trivial improvement (9%, ±11%) in the total 100 shots at the end of the six week period (Table 9). In contrast, the control group had a small improvement (26%, ±32%) in the total 100 shots taken after the final shooting test (Figure 8). Players with a higher baseline shooting score in both groups showed smaller improvement than players with lower baseline scores (r= -0.74, 90% confidence interval -0.48 to -0.87).

**Table 9** – Difference in the shots made (mean, ±90% confidence limits) between the baseline and first post test (post float intervention) and between the baseline and final post test. The standardised magnitude of the change in the mean is described as trivial, small, moderate or large.

<table>
<thead>
<tr>
<th></th>
<th><strong>Experimental Group</strong></th>
<th><strong>Control Group</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First post test</td>
<td>Final post test</td>
</tr>
<tr>
<td><strong>Total 100 Shots</strong></td>
<td>0, ±6 trivial</td>
<td>4, ±5 trivial</td>
</tr>
<tr>
<td><strong>First 50 shots</strong></td>
<td>-2, ±4 trivial</td>
<td>-1, ±4 trivial</td>
</tr>
<tr>
<td><strong>Second 50 shots</strong></td>
<td>2, ±4 small</td>
<td>4, ±4 small</td>
</tr>
</tbody>
</table>
The control group made 4, ±6 (mean, ±90% confidence limits) more three-point shots in the first 50 attempts at the end of the float and video intervention. In contrast, the experimental group had no clear improvement in the first 50 three-point shots at any time during the study. For the second 50 shots, both the control (3, ±4 shots) and experimental (4, ±4 shots) group made a small improvement in the final shooting test. A moderate difference between the groups was evident at the fifth test with the control group showing a dip (-8, ±7) in three-point shooting performance.

The mean and standard deviation of the responses to the questionnaire are shown in Figure 9. The players felt the study overall was useful in improving their three-point shooting (Questions 1-4). Eighteen out of the 19 players agreed that the weekly three-point shooting test helped improve their three-point shooting (Question 5). Most (~70%) felt that the test was not fatiguing and that shooting technique could be maintained throughout the test (Questions 6 & 7). Five players indicated that they did not feel the test was a good indication of their three-point shooting ability (Question 8). Eight out of the ten players (experimental group) felt that the float-video sessions had helped improve their three-point shooting (Question 9) and all but one agreed that the video footage was useful and beneficial for improving their three-point shot.
slightly disagreed with the usefulness of her coaching cues) (Questions 10-12 & 14). Nine out of the ten players involved in the intervention indicated they worked actively on the cues shown to them in training (Question 13). Players reported performing 131 ± 132 (mean ± SD) three-point shots per week during the study in regular and individual practices excluding the three-point shooting test.

![Figure 9 - Responses to the items in the shooting study questionnaire (mean ± SD).](image)

**Discussion**

Both the control and experimental group made small improvements in their three-point shooting over the six week period of the study suggesting a beneficial practice effect. In contrast, the flotation tank recovery combined with video-based training did not have a substantial effect on the experimental group players’ three-point shooting performance, despite 80% subjectively reporting positive benefits. Except for the fifth shooting test (one week post-intervention), the shooting performances overall of the experimental group were no better than those of the control group. The control group’s dip in performance on the fifth shooting test can be explained, to some extent, by one player returning from a minor injury for this test. The findings in the current study contradict the previously reported benefits of separate flotation tank recovery (148) and video-based training (55, 58, 113) on basketball shooting. A three week period of video-based
training combined with 2 x 30 min flotation per week may be insufficient time to achieve improvements in three-point shooting performance with highly skilled performers, and a longer or more individually targeted training program may be necessary. While previous flotation interventions had durations of approximately 50-60 min (9, 96, 149), we chose a relative short period of 30 min for effective use of time. Longer periods within the flotation tank are impractical for elite athletes due to their time constraints. Positive effects from shorter exposures to flotation tank recovery and video-based training would also make this intervention more attractive to both athletes and coaches.

No additional imagery or relaxation techniques were employed in this study. Previous studies suggest that flotation tank recovery without imagery is sufficient in improving skill performance (149). Our findings indicate that flotation tank recovery and video-based training may be ineffective without imagery training. Additionally, this is the first flotation tank recovery and video-based training study involving elite basketball athletes. Nine players had an average three-point shooting percentage above 50%, indicating a high level of three-point shooting ability. A comparison of the baseline and change scores reveals that those athletes with a higher baseline score were less likely to show a larger improvement in three-point shooting performance. Flotation tank recovery and video-based training appears to be less effective in athletes who have already attained a high degree of proficiency in three-point shooting, supported by the high negative correlation between initial shooting percentage and the magnitude of improvement. However, the large variability in shooting ability in both groups also reflects the underlying heterogeneity of three-point shooting ability, with players from the forward and centre positions shooting less effectively.

To detect clear and substantial effects more easily, future research should recruit elite basketball athletes from similar positions and shooting ability or include a less variable basketball shot such as the free-throw. Shooting a sufficient amount of free-throws is however more time consuming and this needs to be considered when planning subjects’ availability for testing. The unclear difference in shooting improvements between the control and experimental group may also be a result of our outcome-focused measurement of shooting (make or miss). Previous investigators have tried using a more sensitive test measure by quantifying shooting ability on a scale from 1-5 according to what the ball comes in contact with (ring, backboard, only net) (117). This approach may have allowed detecting small improvements in shooting ability more easily.
However, this scoring system would be difficult to undertake in real-time when shot attempts are taken at a rapid pace.

**Conclusions**

It appears that the weekly three-point shooting tests may have helped improve shooting performance over the six week period more than the intervention itself. This conclusion seems logical especially when players reported only a limited number of three-point shots attempted in regular training. Apart from assessing the players’ three-point shooting ability, the shooting test permitted the athletes to perform a high number of three-point attempts in a short time period. The ~two-fold increase in shooting volume seems a more likely explanation for the improved shooting performance observed in both the control and experimental groups.

Combined flotation recovery and video-based training does not elicit a substantial improvement in three-point shooting in elite female basketball athletes. This type of intervention may be more effective for less skilled three-point shooters. Future research would need to investigate whether imagery training, longer exposure times and perhaps a simpler motor task would yield substantial performance benefits in both less and higher skilled players.

Coaches and support staff are encouraged to utilise practice tasks and games that increase the volume of three-point shots taken by their athletes. If flotation tank recovery and video-based training are to be incorporated, then longer exposure times and intervention periods may be necessary to achieve substantial improvements in three-point shooting performances.

**Acknowledgements**

The research group thank Basketball Australia and the Australian Sports Commission for endorsing this project. Special thanks also to all the coaches and players that made this project possible. The project was funded by the Australian Institute of Sport London Olympic and Paralympic Research Fund.
Chapter 7
Preparation and development for elite basketball competition requires early physical preparation in the athlete development pathway. Implementing resistance training programs with expert supervision and gym facilities limits the exposure of such training to a large part of the junior basketball population. The following study investigates the effectiveness of an online video-based resistance training program in junior basketball athletes which could be easily administered and improve the physical development of junior basketball athletes.
Online video-based resistance training improves the physical capacity of junior basketball athletes

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Abstract

Junior basketball athletes require a well-designed resistance training program to improve their physical development. Lack of expert supervision and resistance training in junior development pathways may be overcome by implementing an online video-based program. The aim of this study was to compare the magnitude of improvement (change) in physical performance, strength and functional movement patterns of junior basketball athletes employing either a fully supervised, or an online video-based resistance training program. Thirty-eight junior basketball athletes (males n=17; age 14 ± 1 y; height 1.79 ± 0.10 m; mass 67 ± 12 kg; females n=21; age 15 ± 1 y; height 1.70 ± 0.07 m; mass 62 ± 8 kg; mean ± SD) were randomly assigned into a supervised resistance training group (SG, n=13), video training group (VG, n=13) or control group (CG, n=12) and participated in a six week controlled experimental trial. Pre- and post-testing included measures of physical performance (20 m sprint, step-in vertical jump, agility, sit and reach, line drill, Yo-Yo intermittent recovery level 1), strength (15 s push up and pull up) and functional movement screening (FMS). Both SG and VG achieved 3-5%, ±2-4% (mean, ±90% confidence limits) greater improvements in several physical performance measures (vertical jump height, 20 m sprint time and Yo-Yo endurance performance) and a 28%, ±21% greater improvement in push up strength compared to the CG. The SG attained substantially larger gains in FMS scores over both the VG (12%, ±10%) and CG (13%, ±8%). Video-based training appears to be a viable option to improve physical performance and strength in junior basketball athletes. Qualified supervision is recommended to improve functional movement patterns in junior athletes.

Keywords: strength training, internet-based intervention, functional movement screen, unsupervised training
**Introduction**

The physical abilities of junior basketball athletes can influence the level of competition they reach (37, 64). A well-developed physique is associated with increased court time (68) and basketball-specific fitness measures (29). Increasing the physical capacity through resistance training for junior athletes improves musculo-skeletal characteristics, reduces injury risk and enhances motor performance (41). The long-term development of junior basketball players should focus on increasing their physical abilities throughout a conditioning program incorporating resistance training (13, 41).

Resistance training forms an integral part of developing the physical abilities of high level basketball players (142). An 18 month basketball training program can improve aerobic fitness levels and reduce percentage body fat, however substantial gains in muscle strength or joint mobility are difficult to achieve from basketball training alone (159). Several research studies have demonstrated that supervised short-term resistance training programs with junior athletes can elicit substantial gains in strength and performance measures in basketball (20, 22, 93, 134), soccer (106, 166), tennis (10), rugby (33, 143) and handball (54). A supervised 10-week complex training (resistance plus plyometric training) intervention elicited significant improvements in upper and lower body explosiveness in adolescent basketball players (134). These increases in fitness were also significantly greater than a control group that only completed basketball training. These findings support the need for effective short-term resistance training programs to improve strength and physical performance in junior basketball athletes.

Improvements in physical abilities are often small in magnitude and require a considerable investment of time and resources (72, 119). For example, two years of training were necessary to achieve small substantial gains in vertical jump height in national female basketball athletes, while national male athletes failed to improve vertical jump height over the same period (36). Access to gym equipment is limited, can be impractical and should not be used by novice athletes without expert supervision (41). To enhance the progression of fitness and conditioning in junior athletes, the issue of how to implement well-designed resistance training programs to athletes at an earlier stage in their development must be addressed.
The lack of a well-designed supervised training program for junior athletes may be overcome with use of an online video-based resistance training program. A more contemporary media-based intervention that outlines general and specific details of the exercises and lifting techniques in the absence of a specialist strength and conditioning coach may be an effective option. Whether an online video-based resistance training program is effective in comparison to supervised or no strength training is unclear. The aim of this study was to compare the magnitude of improvement (change) in strength, functional movement patterns and physical performance of junior basketball athletes after six weeks of resistance training, employing either a fully supervised or an online video-based instruction program.

**Methods**

*Experimental approach to the problem*

A longitudinal controlled experimental trial was conducted to quantify the effects of a fully supervised and an instructional online video-based resistance training program on strength, functional movement patterns and physical performance measures in junior basketball players. Two experimental groups (supervised and video) underwent double baseline testing, followed by a six week training period, and finally post testing in-season (February-March). A third control group completed the testing, but did not receive any resistance training during the study period.

**Subjects**

Thirty nine (males n=17; age 14 ± 1 y; height 1.79 ± 0.10 m; mass 67 ± 12 kg; females n=22; age 15 ± 1 y; height 1.70 ± 0.07 m; mass 62 ± 8 kg; mean ± SD) adolescent basketball players were recruited for the study. All subjects were part of a state squad in their age group and/or a state-level development program and undertaking a minimum of three basketball training sessions plus one game a week. None of the athletes had prior experience in resistance exercise and all were classified as beginners in strength training. The subjects were allocated into the supervised (SG; n=13), video (VG; n=13) or control (CG; n=13) group with the aim of minimising differences in group means of age, gender and strength scores achieved at baseline testing (69). Subjects needed to complete a minimum of 75% of the training sessions to be included in the final data analysis. Written informed consent was obtained from all participants and their parents or guardians. The research project was approved by the Australian Institute of Sport (20101207) and Charles Sturt University (2011/013) Ethics Committees.
Procedures

Testing

Subjects were tested twice in the two weeks prior to the six week training period and post testing occurred in the week after training was completed. Each testing phase was divided into two testing sessions on different days. The first session involved a battery of basketball-specific physical tests, while the second session comprised functional movement screening (FMS), power and strength testing. All subjects were encouraged to come to testing well-rested (no heavy exertion 24 h prior), hydrated and at least 2 h after a light snack or meal.

Subjects underwent basketball-specific physical testing on a Monday or Tuesday morning at 7 am prior to school commitments. Performance measures of physical ability included speed (20 m sprint), vertical jump height, agility, anaerobic (line drill test) and aerobic capacity (Yo-Yo intermittent recovery level 1 test; Yo-Yo IRL1) conducted under standardized conditions (145). Most athletes had performed these tests previously and hence minimal learning effects were assumed. Subjects performed a 15 min standardized warm up protocol prior to being tested.

Functional movement screening, countermovement jump height (CMJ) and strength were assessed five days later. Functional movement patterns were evaluated using seven screening tests (overhead squat, hurdle step, in-line lunge, shoulder mobility, straight leg raise, push up and rotary stability) as outlined by Kiesel et al. (83) and Minick et al. (101). In addition, a landing screen was included to assess landing technique. The FMS was used to evaluate changes in functional movement competency. Subjects conducted two trials of each movement and the best movement pattern was scored. The movement patterns were rated by a Certified Strength and Conditioning Specialist according to a four point scale (0-3) and screens involving a right/left side component were rated with the lower of the 2 scores. The individual FMS scores were summated to compute a total score (FMS Sum8). All participants conducted 3 clearance screens before FMS (101). All trials were filmed from the frontal and sagittal plane to allow repeated scoring of the FMS. Test-retest reliability for the FMS was evaluated by 8 experts from the strength and conditioning and physiotherapy fields. Ten subjects were randomly selected and scored twice by each expert with at least 1 month between scoring.

Countermovement jump height was measured to assess the capabilities of the lower extremity in the long stretch-shortening cycle. Countermovement jump testing was conducted on a force plate fitted with a linear position transducer using Ballistic
Measurement System software (Fitness Technology Inc., South Australia, Australia). Subjects performed 2 sets of 3 maximal CMJs with a three min rest interval between sets. Jumps were performed with an aluminium pole held to the upper part of the back at the base of the neck (m. trapezius) which was attached to the position transducer and eliminated any arm swing. Warm-up consisted of two sets of five jumps at 70% and 90% of maximum effort respectively. Subjects were instructed to stand ‘still and straight’ at the beginning of data collection and then to jump as ‘fast and high’ as possible. No hip, knee or ankle flexion was allowed during the flight phase to ensure valid trials. The best jump height from both sets of CMJs was used for analysis.

Strength was measured using a 15 s push up and modified pull up test as outlined by Negrete et al. (108). Push ups were counted using a push button device which released an auditory signal when pressed by the subject’s chest. The device had a height of 6.5 cm and ensured all subjects reached the same depth for all push ups. The push up test was performed in the standard position (87): hands positioned slightly wider than shoulder width apart with the trunk held in a rigid straight position with support on the toes. Subjects who were unable to perform one correct repetition during the warm up assumed a modified push up position with support on their knees. The number of push ups completed that produced audio signals in the 15 s bout was recorded.

The modified pull up was performed on a Smith Machine with a bench positioned under the subject’s feet. Subjects assumed a supine position with their heels on the bench and held on to a bar with a pronated grip. The bar was positioned in line with the shoulders, just above arms’ reach when the subject lay supine on the floor. Subjects were instructed to lift their hips to form a straight body with their arms still fully extended and maintain this rigid trunk posture throughout the test. Full range of motion was enforced by ensuring the subject achieved an elbow flexion of at least 90 degrees (upper arms are parallel to the floor). The number of successful repetitions within the 15 s period was recorded. Only one maximum effort trial was conducted with these tests to avoid fatigue effects in this subject group. Using three maximal trials for each test, Negrete et al. (108) calculated intra-class correlation coefficients for the push up and modified pull up test of 0.958 and 0.989, respectively.

Training program
The Supervised training group (SG) trained twice a week for approximately an hour with two rest days between sessions. Subjects from the supervised group trained in the early mornings on Monday and Thursday or Tuesday and Friday. Subjects from the
video group (VG) could choose their own training times but were advised to keep the same training days and maintain a two day recovery period. The training program was designed by the principal researcher using a strength and conditioning software package (Visualcoaching Pro 2.0.2.0, VisualCoaching Pty Ltd, Melbourne, Australia) and was the same for both training groups. The training program was planned so that all exercises could be conducted on a basketball court. Hence, all exercises incorporated the use of body weight resistance and available objects and equipment, such as a chair, towel and basketballs. The training program incorporated the following exercise elements: landing technique, agility/change of direction, jumping technique, squatting technique, lunge technique, push ups, towel pull ups, dips, trunk/stability exercises. Training progression over the six week intervention was ensured through an increase in volume with more repetitions and/or a small modification of the exercise to increase intensity.

Supervised training involved small group sessions with a maximum of six participants and a minimum of two experienced strength and conditioning coaches, ensuring a 3:1 athlete-to-coach ratio. Subjects received verbal, visual and kinaesthetic feedback on proper exercise technique and were given strong verbal encouragement to complete the prescribed number of sets and repetitions.

Online video-based training required the subjects to log in to a website where the training programs were presented. A new training program was uploaded each week to ensure the subjects followed the planned progression of exercises. The exercises were described in full detail with tips and cautions, as well as a video clip demonstrating the correct execution of the exercise. Subjects had the option of printing out the program and instructions or to access the information via a mobile device to refer to during training. All subjects were asked to complete an online training diary to assess compliance to the training program.

Statistical analysis
To avoid the shortcomings of research based in null-hypothesis significance testing, magnitude-based inferences and precision of estimation were employed (11). Performance measures were log-transformed prior to analysis to reduce the non-uniformity of error. The best result achieved in the double baseline testing was used as the criterion baseline measure. Magnitude-based inferences on the differences in the mean (pre to post) changes between the three treatment groups were determined. Qualitative descriptors of standardized effects were assessed using these criteria: trivial
Precision of estimates was indicated with 90% confidence limits, which defines the range representing the uncertainty in the true value of the (unknown) population mean. Effects with confidence limits overlapping the thresholds for small positive and negative effects (exceeding 0.2 of the standard deviation on both sides of the null) were defined as unclear. Clear small or larger effect sizes were defined as substantial. Test-retest reliability was calculated from the typical error of measurement and intraclass correlation coefficient.

**Results**

One control subject was unable to complete the post-testing due to a basketball-related injury and was excluded from analysis. Training logs from the online diary revealed 96% compliance from the supervised group and 77% compliance from the video group. In the supervised group, three subjects missed one session and one subject missed three sessions due to illness. The training logs did not reveal all causes for the lower compliance in the video group. Only five subjects from the video group completed all 12 sessions while two subjects were excluded from the final analysis for low compliance (<75%). Illness was anecdotally reported in some cases. Final data analysis included a total number of 36 subjects (SG n=13, VG n=11, CG n=12).

**Physical testing results**

Substantial changes in physical performance can be seen for all groups (Table 10). The control group’s performance deteriorated or remained similar to baseline in all physical tests except for the agility test (-1.5%, ±1.6%, mean, ±90% confidence limits; small, qualitative inference). The supervised and video groups made small improvements in vertical jump height (5.4%, ±2.4% and 4.3%, ±2.7% respectively) and agility (-2.2%, ±2.2% and -3.8, ±1.1%). The supervised group additionally had a small increase in Yo-Yo IRL1 scores (35%, ±28%; small). Trivial or unclear changes occurred in 20m sprint time (-0.5%, ±1.0% and -1.6%, ±2.0%) and line drill performance (0.5%, ±2.1% and -0.9%, ±1.4%) for the supervised and video groups. Sit and reach distance remained trivial for the supervised group (-1.2%, ±1.1%), but declined for the video group (-1.6, ±1.7%) and control group (-1.9%, ±1.3%). Differences between the supervised and video group were trivial or unclear in vertical jump, sit and reach and 20m sprint performance. The video group had greater improvements in agility (-1.7%, ±2.4%; small) and line drill (-1.4%, ±2.5%; small) performance than the supervised group. The
supervised group showed better Yo-Yo IRL1 performance (-18%, ±31%; small) than the video group.

**Strength test results**

There was a substantial increase in the CMJ in the supervised group (5.0%, ±4.2%; small) and a substantial decrease in the control group (-4.6%, ±6.2%; small). The change in the video group was unclear. The supervised group had a substantially larger mean change in CMJ height than the control group (-9.2%, ±7.3%; moderate), but with little difference compared to the video group (-4.2%, ±8.0%; unclear).

Both the supervised and video groups had small increases in the number of push ups performed (20%, ±13% and 23%, ±15%). The control group had a substantial decrease in push ups (-13%, ±17%; small). While the experimental groups had substantial differences in the mean changes to the control group, differences between the supervised and video group in push up strength were unclear (Table 11). No clear changes were found in the pull up test for the supervised group (1%, ±13%) and video group (1%, ±21%), however the control group had a trivial decrease in pull up strength (-6%, ±18%). Supervised training almost certainly improved FMS scores and moderate-to-large differences were evident between the supervised group and the video and control group. The typical error for FMS intra-test reliability was 4.5% with an intraclass correlation coefficient of 0.82.
Table 10 - Physical testing results for the Supervised Group (SG), Video Group (VG) and Control Group (CG) showing the % change of the pre-post mean and % difference of the mean changes between the groups (S&R is in raw units).

<table>
<thead>
<tr>
<th>Test</th>
<th>Group</th>
<th>Pre</th>
<th>Post</th>
<th>%change</th>
<th>% diff SG-VG</th>
<th>% diff SG-CG</th>
<th>% diff VG-CG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td>Mean, ±CL</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>VJ (cm)</td>
<td>Supervised</td>
<td>43 ± 7</td>
<td>46 ± 6</td>
<td>5.4, ±2.4*</td>
<td>-1.0, ±3.5 trivial</td>
<td>-4.5, ±4.1 small</td>
<td>-3.6, ±4.2 trivial</td>
</tr>
<tr>
<td></td>
<td>Video</td>
<td>41 ± 7</td>
<td>43 ± 7</td>
<td>4.3, ±2.7*</td>
<td>-1.0, ±3.5 trivial</td>
<td>-4.5, ±4.1 small</td>
<td>-3.6, ±4.2 trivial</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>44 ± 8</td>
<td>44 ± 9</td>
<td>0.6, ±3.5t</td>
<td>-1.0, ±3.5 trivial</td>
<td>-4.5, ±4.1 small</td>
<td>-3.6, ±4.2 trivial</td>
</tr>
<tr>
<td>S&amp;R (cm)</td>
<td>Supervised</td>
<td>5 ± 8</td>
<td>4 ± 8</td>
<td>-1.2, ±1.1t</td>
<td>-0.5, ±2.0 unclear</td>
<td>-0.8, ±1.7 trivial</td>
<td>0.3, ±0.21 unclear</td>
</tr>
<tr>
<td></td>
<td>Video</td>
<td>3 ± 6</td>
<td>1 ± 8</td>
<td>-1.6, ±1.7*</td>
<td>-0.5, ±2.0 unclear</td>
<td>-0.8, ±1.7 trivial</td>
<td>0.3, ±0.21 unclear</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>6 ± 8</td>
<td>5 ± 9</td>
<td>-1.9, ±1.3*</td>
<td>-0.5, ±2.0 unclear</td>
<td>-0.8, ±1.7 trivial</td>
<td>0.3, ±0.21 unclear</td>
</tr>
<tr>
<td>Agility (s)</td>
<td>Supervised</td>
<td>6.47 ± 0.41</td>
<td>6.33 ± 0.49</td>
<td>-2.2, ±2.2*</td>
<td>-1.7, ±2.4 small</td>
<td>0.6, ±2.6 unclear</td>
<td>2.4, ±1.9 small</td>
</tr>
<tr>
<td></td>
<td>Video</td>
<td>6.55 ± 0.40</td>
<td>6.29 ± 0.33</td>
<td>-3.8, ±1.1*</td>
<td>-1.7, ±2.4 small</td>
<td>0.6, ±2.6 unclear</td>
<td>2.4, ±1.9 small</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>6.32 ± 0.35</td>
<td>6.22 ± 0.38</td>
<td>-1.5, ±1.6*</td>
<td>-1.7, ±2.4 small</td>
<td>0.6, ±2.6 unclear</td>
<td>2.4, ±1.9 small</td>
</tr>
<tr>
<td>Line Drill (s)</td>
<td>Supervised</td>
<td>31.35 ± 1.65</td>
<td>31.53 ± 2.21</td>
<td>0.5, ±2.1</td>
<td>-1.4, ±2.5 small</td>
<td>0.8, ±2.7 unclear</td>
<td>2.2, ±2.2 small</td>
</tr>
<tr>
<td></td>
<td>Video</td>
<td>31.34 ± 1.60</td>
<td>31.00 ± 1.53</td>
<td>-0.9, ±1.4t</td>
<td>-1.4, ±2.5 small</td>
<td>0.8, ±2.7 unclear</td>
<td>2.2, ±2.2 small</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>30.79 ± 1.60</td>
<td>31.20 ± 1.72</td>
<td>1.3, ±1.9</td>
<td>-1.4, ±2.5 small</td>
<td>0.8, ±2.7 unclear</td>
<td>2.2, ±2.2 small</td>
</tr>
<tr>
<td>20m Sprint (s)</td>
<td>Supervised</td>
<td>3.58 ± 0.19</td>
<td>3.56 ± 0.21</td>
<td>-0.5, ±1.0t</td>
<td>-1.1, ±2.2 trivial</td>
<td>3.2, ±2.9 small</td>
<td>4.4, ±3.3 small</td>
</tr>
<tr>
<td></td>
<td>Video</td>
<td>3.58 ± 0.25</td>
<td>3.52 ± 0.20</td>
<td>-1.6, ±2.0t</td>
<td>-1.1, ±2.2 trivial</td>
<td>3.2, ±2.9 small</td>
<td>4.4, ±3.3 small</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>3.40 ± 0.19</td>
<td>3.50 ± 0.22</td>
<td>2.7, ±2.8*</td>
<td>-1.1, ±2.2 trivial</td>
<td>3.2, ±2.9 small</td>
<td>4.4, ±3.3 small</td>
</tr>
<tr>
<td>Yo-Yo (m)</td>
<td>Supervised</td>
<td>822 ± 640</td>
<td>978 ± 528</td>
<td>35, ±28*</td>
<td>-18, ±31 small</td>
<td>-31, ±30 small</td>
<td>-15, ±18 small</td>
</tr>
<tr>
<td></td>
<td>Video</td>
<td>797 ± 385</td>
<td>834 ± 414</td>
<td>10, ±14t</td>
<td>-18, ±31 small</td>
<td>-31, ±30 small</td>
<td>-15, ±18 small</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>916 ± 370</td>
<td>862 ± 363</td>
<td>-6.8, ±12.1t</td>
<td>-18, ±31 small</td>
<td>-31, ±30 small</td>
<td>-15, ±18 small</td>
</tr>
</tbody>
</table>

*substantial change, t - trivial change, CL: 90% confidence limits
Table 11 – CMJ, strength test and Functional Movement Screen (FMS) results of the Supervised Group (SG), Video Group (VG) and Control Group (CG).

<table>
<thead>
<tr>
<th>Test</th>
<th>Group</th>
<th>Pre Mean ± SD</th>
<th>Post Mean ± SD</th>
<th>% change Mean, ±CL</th>
<th>% diff SG-VG Mean ±CL Inference</th>
<th>% diff SG-CG Mean ±CL Inference</th>
<th>% diff VG-CG Mean ±CL Inference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CMJ (cm)</strong></td>
<td>Supervised</td>
<td>39 ± 5</td>
<td>41 ± 6</td>
<td>5.0, ±4.2*</td>
<td>-4.2, ±8.0 unclear</td>
<td>-9.2, ±7.3 moderate</td>
<td>-5.2, ±9.1 small</td>
</tr>
<tr>
<td></td>
<td>Video</td>
<td>38 ± 6</td>
<td>37 ± 5</td>
<td>-0.6, ±7.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>39 ± 5</td>
<td>38 ± 8</td>
<td>-4.6, ±6.2*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Push Up</strong></td>
<td>Supervised</td>
<td>8 ± 3</td>
<td>9 ± 3</td>
<td>20, ±13*</td>
<td>1.9, ±19.8 unclear</td>
<td>-28, ±21 moderate</td>
<td>-29, ±22 moderate</td>
</tr>
<tr>
<td></td>
<td>Video</td>
<td>8 ± 3</td>
<td>9 ± 3</td>
<td>23, ±15*</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Control</td>
<td>7 ± 4</td>
<td>7 ± 4</td>
<td>-13, ±17*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pull Up</strong></td>
<td>Supervised</td>
<td>8 ± 3</td>
<td>8 ± 3</td>
<td>1, ±13</td>
<td>-0.2, ±24.1 unclear</td>
<td>-7.0, ±21.2 unclear</td>
<td>-6.8, ±26.9 unclear</td>
</tr>
<tr>
<td></td>
<td>Video</td>
<td>8 ± 2</td>
<td>8 ± 3</td>
<td>1, ±21</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>8 ± 4</td>
<td>7 ± 3</td>
<td>-6, ±18*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>FMS Sum8</strong></td>
<td>Supervised</td>
<td>14 ± 1</td>
<td>16 ± 2</td>
<td>14, ±5*</td>
<td>-12.1, ±9.6 moderate</td>
<td>-13.0, ±8.3 large</td>
<td>-1.1, ±10.5 unclear</td>
</tr>
<tr>
<td></td>
<td>Video</td>
<td>14 ± 2</td>
<td>14 ± 2</td>
<td>0.1, ±8.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>14 ± 2</td>
<td>14 ± 1</td>
<td>-1, ±7</td>
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</table>

* substantial change. Sum8 = sum of eight individual FMS scores. CL: 90% confidence limits.
Discussion

The analysis of the experimental controlled trial revealed substantial improvements in several measures of physical performance for the experimental groups after a six week resistance training intervention. Both short-term supervised and online video-based resistance training were effective in improving physical performance measures and strength. The supervised group made superior gains in endurance (Yo-Yo IRL1), whereas the video-group had larger improvements in acceleration and change of direction tasks (agility, line drill). A larger resistance training volume (and possibly cumulative fatigue) in the supervised group may have impaired their ability to achieve superior gains in acceleration tasks compared to the video group. As endurance and cardiovascular adaptations were not targeted specifically in the training program, the increase in Yo-Yo IRL1 performance by both experimental groups is presumably related to improvements in movement efficiency. These findings demonstrate the effectiveness of short-term resistance training programs for improving physical performance in adolescent basketball athletes (20, 22, 134). While previous research has focused on off-season training programs, the results from our study show that positive gains can also be achieved in-season with junior basketball athletes (134). Enhancements in our physical performance measures (20m sprint, step in vertical jump, Yo-Yo IRL1) also indicate the usefulness of resistance training for improving the sport-specific locomotor performance of basketball athletes.

Substantial gains in strength and speed-strength were also identified in both experimental groups. Lower extremity speed-strength in the long stretch-shortening cycle (CMJ) improved substantially by 5% in the supervised group. Short-term improvements in vertical jump ability are most likely due to enhanced inter- and intra-muscular coordination (127). Jumping and landing technique was emphasized at the start of training sessions and verbal feedback was given regarding jumping technique in the supervised group. The increase in vertical jump height likely reflects both neuromuscular adaptations and improved technique. Both the supervised and video groups had substantial improvements in the number of push ups achieved in the 15 s push up test. Push ups were a main component of the training program and had high conformity with the test protocol, thus allowing maximal transfer of strength adaptations to the performance measure. This was not the case with pull up strength. Neither of the experimental groups had clear gains in the 15 second pull up test. Due to the constraints of the training environment (basketball court), no supine pull up exercise
could be included in the training program. Instead, a vertical towel pull-up exercise was used to train the posterior upper body musculature. Although an increase in repetitions was achieved during training in this exercise, these strength gains did not appear to transfer to the supine pull up test. A vertical pull up test was not used due to the lack of strength in this adolescent athlete population.

Functional movement patterns form the basis of physical performance and skill technique (31). Poor functional movement patterns are likely associated with decreased fitness and increased injury risk (83), although these findings remain to be confirmed in other groups (111, 144). Poor landing technique has been associated with ACL injuries (1) but can be improved with plyometric and strength training (2). Supervised training which provides verbal and kinaesthetic feedback to the athlete can enhance motor learning and therefore have a greater impact on modifying movement patterns. Supervised training was the only training format that improved functional movement screening scores in our study. This finding supports the need for expert supervision to enhance movement patterns and that this benefit is less likely in unsupervised exercise programs. FMS intra-rater reliability has previously shown to be good (42, 101, 141, 144). Our evaluation of FMS intra-tester reliability suggests non-certified experts in strength and conditioning or physiotherapy can reliably score functional movement screens.

This is the first study to demonstrate positive effects of an online video-based resistance training program in junior athletes. Similar online physical activity interventions have been applied to an adult population and yielded benefits on physical activity (160, 162). Unsupervised strength training programs for adolescent rugby athletes without media interaction have showed positive benefits, although these have been mostly smaller in magnitude when compared with supervised training (33, 143). The resistance training program used in this research project was solely conducted on the basketball court. The evidence that this type of program can induce positive adaptations in strength and physical performance has an important practical application. Gym facilities with adequate resistance training equipment and expert supervision are often limited and less accessible for junior athletes. A court-based resistance training program offers an effective solution and has been previously shown to improve physical performance in adolescent basketball athletes (20).

The outcomes of this study need to be interpreted within the following limitations. To standardize the workload, the resistance training program was equal for all subjects.
Maturation and gender effects may therefore explain the large degree of variation in some of our performance measures. The procedure for conducting functional movement screens was limited to the information available in the literature (83, 101). Certification in functional movement screening could possibly increase the scoring precision and intra-rater reliability. The training intervention employed in this study was of a short six week period. Whether an online video-based resistance training program yields more substantial benefits over a longer period remains unclear. Further longitudinal research is required to evaluate whether internet-based interventions are effective in senior basketball players and other sports.

In summary, an online video-based resistance training program is a viable option to improve the physical capacity of junior basketball athletes. Supervised training and expert program design is necessary to provide feedback on correct movement patterns, lifting techniques and progression of exercises.

**Practical applications**

Supervised training remains the best method of program delivery to achieve maximum compliance, test performance and individualized feedback. In circumstances where supervised training is not available, online video-based training could be used to elicit substantial improvements in physical performance and strength in junior basketball athletes. This form of media-based training is a cost-effective and practical solution to apply resistance training to a large and/or remote athlete group. Sporting bodies could utilize this strategy to educate coaches and athletes on how to implement resistance training exercises into their daily training environment and enhance the short-term physical development of junior athletes. A combination of supervised and online video-based training may offer larger benefits than online video-based training alone.

**Acknowledgements**

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University. The authors or institutions listed have no affiliation with VisualCoaching Pty Ltd. The results of this study do not constitute an endorsement of VisualCoaching Pro by the authors or the NSCA.
Chapter 8
Discussion

Development of junior basketball athletes is based on the specificity of preparation for competition. Basketball training programs should be tailored individually towards competition-specific demands. There are substantial differences in physical, physiological, tactical and technical demands between a multi-game tournament and seasonal (weekly games) competition in elite junior basketball athletes. To prescribe competition-specific training programs the number of players, court size and work-to-rest ratios can be manipulated in small-sided basketball games to achieve specific training objectives. However off-court flotation tank recovery and video-based training does not appear to elicit substantial improvements in three-point shooting. In contrast, six weeks of online video-based resistance training elicited improvements in physical performance, strength and functional movement. Taken together, the results of this series of studies suggest the long-term development of junior basketball athletes should incorporate selected on- and off-court training interventions that meet the specific needs of tournament and seasonal competitions.

Elite basketball athletes typically play in two different competition formats including international tournament competition and national seasonal competition. International level tournament competition involves several games within a time frame of 8-10 days, whereas in seasonal competitions single games are typically played on a weekly basis. Specific preparation towards seasonal competition should predominately target anaerobic fitness and the ability to repeat high intensity efforts conducive to a faster style of game with higher movement frequencies. This approach is consistent with previous recommendations emphasising agility training in basketball conditioning to account for the frequent changes in movement patterns (16, 138). Chapter 3 of this thesis highlighted that international tournament competition had fewer high intensity and shuffling movements, and more time spent in submaximal heart rate zones. These physical and physiological demands reflect the tactical demands of tournament competition. Shuffling and high intensity movements are lower in tournament games due to fewer possessions per game and a more controlled style of play. Within an international tournament, the increased intensity is indicated by more time spent in high heart rate zones and an increase in the mean heart rate as the tournament progresses. Interestingly, the number of high intensity movements increased whereas the frequency of low intensity movement patterns decreased, most likely related to fatigue and/or increased intensity of games towards the semi-finals and medal playoffs.
Long-term preparation for tournaments should aim at minimising the reduction in movements and developing the cardiovascular capacity to maintain near maximal heart rates for extended periods of play. The duration of play within a game for both tournament and seasonal games was on average 1.5 min interspersed with mean break periods of 1 min duration. Developing sufficient aerobic capacity and neuromuscular resilience could be achieved by including conditioning drills in practice with similar work-to-rest ratios. Short-term strategies for tournament competition could include implementation of recovery strategies such as cold-water immersion (103, 114, 125) or tactical measures such as frequent player rotations and a more half-court oriented playing style. Ball reversals, off-ball screens, dribble penetration and on-ball screens were described as the most frequent tactical elements in chapter 3. Tactical preparation for both season and tournament competition should emphasise frequent ball reversals during offence. This tactical element forces the defence to shift from one side of the court to the other, providing opportunities for the offence to attack while the defence is perturbed. Further research should investigate the effectiveness of different half-court style tactics in tournament competition.

A key focus for basketball coaches is developing the technical abilities of their athletes. It is often debated which skills are critical for success in basketball competition. Unfortunately, research into the key performance indicators of basketball games has predominately focused on seasonal domestic competition (53, 75, 132). The cross-sectional analysis of under 17, under 19 and senior male and female World Championship box score data in chapter 4 of this thesis showed that field-goal scoring, free throws made and offensive rebounds are key skills required in senior and male World Championships. Possession (turnovers, fouls, steals) and defensive pressure (defensive rebounds, blocked shots, turnovers) are discriminating factors in female and junior World Championships. This information can guide technical skill preparation for a specific event and long-term development of junior basketball athletes. National sporting bodies should structure the coaching curriculum and athlete development pathway according to specific events in the yearly calendar. Clearly players must become effective scorers at the senior level and in male events. Junior and female players must focus on containment and denial abilities to apply defensive pressure as well as good ball handling and passing skills to maintain control of the ball. Long-term junior development goals during non-competition phases should emphasise shooting and other scoring skills, while short-term preparation for junior World Championships should include defensive and possession skills and tactics.
Small-sided games are a popular training methodology in basketball practice and can be modified to achieve specific training outcomes. The number of players, court size and work-to-rest ratios of commonly used small-sided basketball games can be manipulated to achieve specific training objectives. In this way, training can address the specific demands of upcoming tournaments, either a major national or international championship-style tournament, or a weekly season competition. Heart rates and RPE scores in chapter 5 confirm the suggestion that physiological demands can be increased by reducing the number of players in small-sided basketball games (27, 128). Decreasing the number of players in a small-sided game has the largest impact on the physical, physiological and technical demands. Changing court size and work-to-rest ratios alter these demands to a lesser degree. Additionally, changing the court size and work-to-rest ratio have converse effects on the physical and physiological demands. Using full court drills with a high work-to-rest ratio can increase the physiological demands (increase in RPE, mean heart rate and time spent in higher heart rate zones) but simultaneously reduce physical demands (in terms of movement frequency and intensity). When preparing for specific demands of competition, small-sided games with fewer players (e.g. 2v2) on the full-court can be employed as game-based conditioning for tournament competition to improve aerobic capacity and fatigue resistance. Considering chapter 3 demonstrated that seasonal competition involves a greater number of high intensity movements, preparation for seasonal competition should include more players in full or half-court small-sided games to increase the number of high intensity movements.

Flotation-tank recovery combined with video-based training failed to improve three-point shooting in elite basketball athletes in chapter 6. However, an important practice effect independent of the video-flotation intervention was evident with small improvements in three-point shooting in both the experimental and control groups after three weeks. No clear difference was observed in changes in shooting ability between the experimental and control group. Previous research studies reporting benefits using similar techniques had longer flotation durations (~1 h), used less variable tests (free-throws, dart throws, archery) and often tested directly after the intervention (9, 149, 164). Further investigations are needed to elucidate the effectiveness of the combined approach with longer exposure times and other forms of shooting such as free-throws. However, this would involve more of the athletes’ time that could be problematic when implementing this form of intervention in an elite training environment. Nonetheless, this study highlighted that improvements in three-point shooting can be made with a
weekly high-volume shooting drill (~100 shots in 5 min) conducted over a six week period in elite basketball athletes though the addition of flotation and visualisation did not improve this effect. Coaches and athletes should be reminded that regular shooting practice is paramount in improving shooting performances.

Being physically resilient is necessary to undertake a substantial volume of training, without sustaining injury, illness or a reduction in performance. Long-term physical development should account for the demands of basketball training and be competition-specific in the lead-up to weekly seasonal games or a multi-game tournament. Supervised resistance training is effective in improving physical performance in junior basketball athletes but requires the use of weight equipment (136). Implementing resistance training programs is often a challenge for junior development programs given a lack of expert strength coaches and gym facilities. Where expert supervision and gym facilities are unavailable, online video-based programs could be delivered from a centralised location and applied on any basketball court. Chapter 7 has demonstrated that strength and conditioning coaches can now administer a supervised resistance program on a basketball court without expensive gym equipment to elicit improvements in functional movement, strength and physical performance. In this form, resistance training is more accessible and available to larger numbers of junior basketball athletes. Online video-based programs provide greater improvements in physical performance than no resistance training at all. This form of program delivery can yield substantial improvements in vertical jump height, agility and push up strength, but is insufficient in eliciting changes in functional movement. Expert supervision is still required to provide immediate feedback on technique, address deficiencies in functional movement and attains higher compliance than unsupervised training. Whether online video-based training is more effective over a longer time period remains to be investigated. Modern technology and software solutions should be employed to assist the implementation of training programs early in the athlete development pathway.

In summary, the preparation of junior basketball athletes should be tailored towards the specific demands of seasonal (weekly) games or multi-game national or international tournaments. Conditioning towards tournament competition should develop the ability to recover quickly between games, and maintain high intensity efforts throughout the competition period (typically 8-10 days). Tactical preparation for tournament competition could involve a more half-court oriented style of play. Technical and tactical demands need to be modified according to the age, level and gender of the
tournament. An offensive emphasis is recommended for senior and male competition whereas a focus on defence and possession is more suitable for junior and female competition. Seasonal competition requires more changes in movement and generally involves a faster paced game. Preparation for seasonal games should emphasise conditioning the anaerobic energy systems and the ability to recover quickly between high intensity efforts within a game.

Adjusting small-sided game variables influences specific training adaptations. Decreasing the number of players in a team has the largest impact on increasing the physical, physiological and technical demands of small-sided basketball games. Increasing court size and work-to-rest ratios can elicit larger physiological responses, but decreases movement intensity and frequency. Shooting is a key technical component in basketball practice that can be improved with regular practice. However more work is needed to refine flotation tank recovery and video-based training interventions. Long-term physical development should form the basis of basketball specific development and preparation. Supervised resistance training, even on a basketball court without weight equipment, is an effective form of program delivery and can improve functional movement, strength and physical performance in junior athletes. Implementing online video-based resistance training programs can assist in the long-term physical development of junior basketball athletes.
Chapter 9
Conclusions

The development and preparation of elite basketball athletes needs to take competition-specific demands into account. Conditioning for seasonal competition requires a larger emphasis on agility training and the ability to repeat high intensity efforts within a game. Tournament competition requires athletes to maintain high intensity efforts from game to game. Training for tournaments should focus on developing a high level of aerobic capacity to recover between games, and neuromuscular resiliency to maintain and increase the frequency of high intensity movements in a tournament. Short-term tactical preparation for tournament competition could involve a more controlled structure equivalent to that of international tournament competition by emphasising a half-court style of play. Seasonal competition involves a higher number of possessions indicating a faster style of play.

Technical and tactical preparation for junior and female World Championship tournaments should emphasise defensive pressure and possession. Long-term development for elite junior basketball athletes should focus on scoring skills as offensive performance indicators are associated with higher rankings in senior and male World Championships.

Decreasing the number of players in small-sided games is the main variable coaches can manipulate to increase physical, physiological or technical adaptations. Using full-court small-sided games increases the physiological demands, however simultaneously reduces the number of high intensity movements and technical elements. Using longer work periods with less rest has a similar effect by eliciting higher cardiovascular responses but reducing the frequency of high intensity movements. Shorter work periods with sufficient rest and using the half court, increases the number of movements and the frequency of technical elements. Thus, coaches can modify small-sided basketball games according to specific training objectives.

Flotation tank recovery and video-based training is not effective in improving three-point shooting in elite female basketball athletes. Regular practice of three-point shooting including a high number of repetitions on a weekly basis can elicit small improvements in three-point shooting in elite basketball athletes. Regular shooting practice should remain a focus for coaches and players to improve scoring abilities.

On-court supervised resistance training can improve the long-term physical development of elite junior basketball athletes with increases in physical performance,
strength and functional movement. When supervised training is unavailable, online video-based resistance training programs promote substantial improvements in physical performance and strength, and offer a better alternative to no resistance training at all. National sporting bodies should support physical aspects of junior development through the use of online video-based conditioning programs.
Practical applications

The following practical applications emanate from this thesis:

- Preparation for tournament competition should differ from that of seasonal competition. Players need well developed aerobic fitness and neuromuscular resilience to minimise the effects of fatigue that occurs over the duration of a multi-game tournament.

- Preparation for seasonal competition should emphasise conditioning anaerobic fitness via repetition of high intensity intervals, and the ability to recover quickly between high intensity efforts within a game.

- Coaches should consider slower, more structured styles of play with frequent ball reversals which may be more suited to tournament competition. Skills that allow efficient ball reversals such as passing and leading may need more attention than previously thought.

- Tactical preparation for seasonal competition should take the faster style of game into account by focusing on offensive and defensive transitions and dribble penetration.

- Scoring remains a highly important skill in the development of elite senior basketball athletes. Players and coaches should focus on improving scoring abilities. Shooting and other scoring skills, such as lay-up techniques and post moves, should be emphasised. The importance of scoring abilities in the development of junior basketball athletes should be highlighted in coach education and the establishment of coaching curricula.

- Coaches can adjust their emphasis of preparation depending on the gender and age group they are coaching, and whether a high ranking at the end of a tournament is a high priority. Defence and possession are associated with high rankings in female and junior competition and require proportionately more attention than scoring.

- Understanding the effect of different training variables on the demands of small-sided games allows coaches to effectively prescribe this popular form of practice. Manipulating the number of players, court size and work-to-rest ratios provide specific training stimuli which can be used to achieve desired training
outcomes. Identifying the converse effects of court size and work-to-rest ratios on the physiological and physical demands informs the programming of small-sided games and training load management.

- Flotation tank recovery combined with video-based training does not appear to be effective in improving three-point shooting in elite female basketball athletes. Regular practice including a high-volume of three-point shots (at least 100 in 5 min), in addition to team and individual practices, is important in improving shooting in elite players.

- Supervised resistance training on the basketball court should be incorporated into the daily training environment of junior basketball athletes. Where expert supervision is unavailable, online video-based programs can elicit improvements in physical performance in a large and/or remote athlete group.
Future directions

Future investigations into the demands of competition could quantify magnitudes of difference between tournament and seasonal competition in elite senior competitions, to guide the specific preparation for senior basketball athletes. Collecting physical, physiological and tactical data on a large number of players from different teams is becoming more feasible with improvements in wearable sensor technology and movement tracking. A cross-sectional comparison of elite senior seasonal competition (e.g. Euroleague) and World Championship tournaments would provide further insight into the demands of elite senior competition.

While small-sided basketball games are common in contemporary basketball practice, there are many other forms of training in a basketball program. The demands of other basketball drills including conditioning, shooting, 1v1 and individual skill drills have not been extensively investigated. The influence of these various training modalities within a basketball practice and the overall training demands of basketball athletes are not well understood. An observational longitudinal analysis of the physical and physiological demands of various training modalities in a basketball program will improve the management of training loads for coaches and support staff.

Flotation tank recovery and video-based training may be effective in improving technical abilities if used with longer exposure times, sub-elite basketball athletes and a less variable skill task such as free-throws. The efficiency of this form of intervention in an elite training environment remains to be investigated. Since an important practice effect was identified in this study, further research should evaluate different shooting interventions to improve the quality of shooting practice.

Online video-based resistance training showed physical improvements in junior basketball athletes over a six-week period. Whether larger increases in physical performance, strength and progress in functional movement can be obtained in a longer intervention period remains unknown. Future studies could also investigate the usefulness of a combined approach using supervised, e.g. in a camp-based setting, and unsupervised online training.
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Appendix 1

Australian Conference of Science and Medicine in Sport, Fremantle 2011

Klusemann, M.J., Pyne, D.B., Fay, T., Drinkwater, E.J.

Relationship between functional movement screens and physical performance tests in junior basketball athletes

Deficiencies in physical performance may be attributed to poor basic movement fundamentals. Purpose: We examined correlations between Functional Movement Screen (FMS) scores and fitness test results in male and female junior basketball players. Methods: Thirty nine male and female players (age 14-17 y) undertook a battery of fitness tests including the 20m-sprint, step-in vertical jump, agility, sit and reach, line drill test and the Yo-Yo intermittent recovery level 1 test. Five d later, the seven standard FMS tests (squat, hurdle step, in-line lunge, shoulder mobility, straight-leg raise, push up, and rotary stability) were performed involving one demonstration then two formal trials. The ‘best’ trial was scored on a scale of 0-3 with a maximum total of 21. Strength and power testing included a countermovement jump (CMJ), a 15 s push up and pull up test. The total FMS score (FMSsum7) was determined with a single score for each test where the worst score was used with those screens that involved a right and left side component. Correlations were determined between single and total FMS score and each physical performance test for both genders combined and then separately. The magnitude of correlation was interpreted as: 0-0.1 trivial, 0.1-0.3 small, 0.3-0.5 moderate, and >0.5 large. Results: No substantial correlations were found between FMSsum7 and performance tests for both genders combined. For females, moderate correlations were observed between the FMSsum7 and Yo-Yo test (r= 0.39 ± 0.34; correlation coefficient ± 90% confidence limits), and the agility test (r= -0.41 ± 0.32). Small to moderate relationships were present between the FMSsum7 and the push up, yo-yo and CMJ tests in the male subjects, but correlations were unclear given large variability. Both the push up strength test and the FMS push up screen (r= 0.30 ± 0.26) and the sit and reach test and the straight-leg raise screen (r= 0.43 ± 0.23) had a moderate correlation in both genders combined. The sit and reach test had a large relationship with the straight-leg raise screen in male subjects (r= 0.50 ± 0.32). Conclusion: FMS scores are moderately correlated with endurance and agility in females, and lower body flexibility in males. Deficiencies in some basic movement patterns may reveal potential areas of improvement for physical performance and assist coaches and support staff in training prescription.
Appendix 2

Congress of the European College of Sport Science, Bruges, Belgium 2012
(Poster Presentation)
Klusemann, M.J., Pyne, D.B., Fay, T., Drinkwater, E.J.

Online video-based resistance training improves the physical capacity of junior basketball athletes

Introduction
Junior basketball athletes require a well-designed resistance training program to improve their physical development. Lack of expert supervision and resistance training in junior development pathways may be overcome by implementing an online video-based program. The aim of this study was to compare the magnitude of improvement in physical performance, strength and functional movement patterns of junior basketball athletes employing either a fully supervised, or an online video-based resistance training program.

Methods
Thirty-eight junior basketball athletes (males n=17; age 14±1y; height 1.8±0.1m; mass 67±12kg; females n=21; age 15±1y; height 1.7±0.1m; mass 62±8 kg; mean±SD) were assigned into a supervised resistance training group (SG, n=13), video training group (VG, n=13) or control group (CG, n=12) and participated in a six week controlled experimental trial. Pre- and post-testing included measures of physical performance (20 m sprint, step-in vertical jump, agility, sit and reach, line drill, Yo-Yo intermittent recovery level 1), strength (15 s push up and pull up) and functional movement screening (FMS).

Results
Training logs revealed 96% compliance from the supervised group and 77% compliance from the video group. Both SG and VG achieved 3-5% ± 2-4% (mean±90% confidence limits) greater improvements in several physical performance measures (vertical jump height, 20 m sprint and Yo-Yo endurance performance) and a 28 ± 21% greater improvement in push up strength compared to the CG. The SG attained substantially larger gains in FMS scores than both the VG (12 ± 10%) and CG (13 ± 8%).
Discussion
Both short-term supervised and online video-based resistance training were effective in improving physical performance measures and strength. Supervised training remains the best method of program delivery to achieve maximum compliance, improvements in physical performance and functional movement patterns. In circumstances where supervised training is not available, online video-based training could be used to elicit substantial improvements in physical performance and strength in junior basketball athletes. This form of media-based training is a cost-effective and practical solution to apply resistance training to a large and/or remote athlete group. Sporting bodies could utilise this strategy to educate coaches and athletes on how to implement resistance training exercises into their daily training environment and enhance the short-term physical development of junior athletes.
Appendix 3

Congress of the European College of Sport Science, Bruges, Belgium 2012
(Oral presentation)
Klusemann, M.J., Pyne, D.B., Foster, C., Drinkwater, E.J.

Optimising technical skills and physical loading in small-sided basketball games

Introduction
The organisational pattern of small-sided basketball games defines the balance between physical and physiological demands and technical practice needed for competitive success. Differences in technical, physiological and physical demands of small-sided basketball games related to the number of players, court size and work-to-rest ratios are not well characterised.

Methods
A controlled trial was conducted to compare the influence of number of players (2v2 / 4v4), court size (half / full court) and work-to-rest ratios (2x5 min / 4x2.5 min) on the demands of small-sided games. Sixteen elite male and female junior players (aged 15-19 years) completed eight variations (2 x 2 x 2) of a small-sided game in randomised order over a six week period. Technical elements (e.g. shots, rebounds and passes) and movement patterns were assessed by video analysis. Heart rate responses and rating of perceived exertion (RPE) were measured to assess the physiological load.

Results
There were ~60% more technical elements in 2v2 than 4v4 and ~20% more in half court than full court games. Heart rate (86 ± 4% v 83 ± 5% of maximum; mean ± SD) and RPE (8 ± 2 v 6 ± 2; scale 1-10) were moderately higher in 2v2 than 4v4 small-sided games. The 2v2 format elicited substantially more sprints (36 ±12%; mean ±90% confidence limits) and high intensity shuffling (75 ±17%) than 4v4. Full court games required substantially more jogging (9 ±6%) than half court games.

Discussion
This is the first study to systematically investigate the effect of the number of players, court size and work-to-rest ratios on the various demands of small-sided basketball games. The main finding is that the number of players has the largest influence on the technical, physiological and high intensity movement patterns in small-sided basketball games. Court size and work-to-rest ratios can influence the frequency of various
movement patterns. Basketball coaches can manipulate different variables of basketball drills and small-sided games to vary the technical, physiological and physical demands of their basketball practice. Applying these training concepts will help coaching staff meet specific training and conditioning goals.
Appendix 4

Basketball three-point shooting project questionnaire

Please respond to each statement by placing an X in the appropriate box.

Provide any further comments about the project in the boxes provided.

Control group complete statements 1 – 8

Experimental group complete statements 1 - 14

1. As a result of participating in this project my 3-point shooting has improved

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2. My 3-point shooting technique has changed as a result of participating in this project

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3. I feel more confident about my 3-point shot after participating in this project.

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4. I would recommend participating in similar projects to other players

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5. I feel that the weekly shooting tests have helped improve my 3-point shooting

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6. I found the shooting tests were too fatiguing to maintain my shooting

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<th>Somewhat Agree</th>
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<th>Strongly Agree</th>
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7. *I found that I was able to maintain my shooting technique throughout the shooting tests.*

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<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
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8. *I feel that the shooting tests were a good indication of my 3-point shooting ability* 

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Comments about the shooting tests:

Comments and suggested improvements about the project overall:

During the study period, how many 3-point attempts do you estimate to have shot on average per week apart from the shooting test (including all 3pt shots from indis, team practice etc.)?

CONTROL GROUP FINISH HERE
9. I feel that the float tank video sessions helped improve my 3-point shooting

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<th>Strongly Disagree</th>
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10. I am more aware of how my 3-point shot can be improved because of the float tank video sessions

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11. I found the aspects of my shot identified for improvement in the videos were accurate

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12. I feel that the cues in the videos were useful to improve my 3-point shot

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13. I actively worked on the aspects identified for improvement when at training

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14. I found watching footage of my own 3-point shot to be beneficial

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Comments about the float tank video sessions: