Optimisation of aerobic fitness development in young athletes

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Attestation 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 (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

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Craig Harrison

October 2013

Thesis publications

The contribution of co-authors for publications (e.g. Harrison, C., 80% etc) arising from these studies and from whom approval has been granted for inclusion in this doctoral thesis, is as follows:

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Now to give back.

This thesis is dedicated to my wife Anna, and son Isaac.

"If the sun refuses to shine, I will still be loving you" **- *Led Zeppelin***

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Abstract

Aerobic fitness is important for most team sport players. However, the trainability of aerobic fitness using different approaches in developmental players, accounting for player maturation, is not well understood. Given the additional importance of technical and tactical skill acquisition for developing team sport players, the design, manipulation and quantification of responses and adaptations to small-sided games (SSG) could help reveal optimal training and prescription strategies for young players. Therefore, the purpose of this thesis was to design and determine appropriate training approaches for the development of aerobic fitness in young athletes. Firstly, a novel SSG was developed and thereafter a series of studies were undertaken to examine the effect of various SSG designs and training regimes on the physiological, movement and technical characteristics and performance variables in young players aged 12 to 14 years. Data revealed that players travelled further and at higher overall speeds, experienced higher physiological workloads, and performed more successful technical executions during non sport-specific SSG compared with a sport-specific equivalent. During the non sport-specific SSG, fewer player numbers (i.e. 3 vs. 3) provided a higher stimulus for aerobic fitness adaptation and improved technical executions compared with 4 vs. 4 and 6 vs. 6 games. Higher physiological loads were elicited during continuous 3 vs. 3 SSGs balanced for team selection and players travelled further at higher speeds during balanced games. Balanced and unbalanced team selections, and continuous and intermittent regimes, were interchanged without affecting the quantity and quality of technical executions. However, while manipulation of SSG rules reduced exercise intensity, the quality and quantity of technical executions was increased. The addition of inter-game high-intensity interval running elicited higher player external load and increased the distance travelled at higher running speeds. Perceptual response of players was influenced by external load of the various SSG formats more so than internal load.

A combination of SSGs training and traditional high-intensity interval training was more effective at increasing aerobic fitness in young team sport players than SSGs training alone. In summary, non sport-specific, continuous SSG formats with small playing numbers, balanced team selection and no rule modifications appear to elicit the highest stimulus for aerobic adaptation and are therefore recommended for aerobic fitness development in young team sport athletes. Restricting the time allowed in possession of the ball could be used as a strategy to increase the technical skill capabilities of players, while intermittent regimes are recommend to train the associated demands of higher speed running. Finally, while SSGs can elicit sufficient stimulus for increasing aerobic fitness, the addition of high-intensity interval training to the training regime of young players around peak height velocity provides optimal development.

Chapter 1: Introduction

1.1 Background

Aerobic fitness is a fundamental component of performance for many athletes. Intermittent team sports (e.g. soccer, rugby, netball, hockey, etc) require players to have a high aerobic capacity in order to recover quickly between high-intensity running efforts and sustain these efforts for the duration of a match (Bishop & Spencer, 2004). In addition, the aerobic capacity of team sport athletes substantially influences their technical performance and tactical choices (Chamari et al., 2005) which can have a significant impact on individual and team performance outcomes. Therefore, careful consideration of the most appropriate training approaches, accounting for development and skill status, is required to optimise the physical and technical development of athletes.

While training protocols need to be based on sound theory, they also need to be realistic and practical. Traditionally, training methods for aerobic fitness development have included repeated, high-intensity, intermittent bouts (Helgerud et al., 2007) or long continuous steady state efforts (Baquet et al., 2010). However, despite the proven effectiveness of these generic types of interventions, the acquisition and application of technical skills and tactical understanding is also an important consideration for team sport athletes (Berry, Abernethy, & Côté, 2008). In addition, some athletes lack the experience or motivation to reach and maintain adequate intensities for improvement during high-intensity interval training and therefore find adhering to such protocols difficult. To address these concerns, novel team sport conditioning approaches such as small-sided games (SSGs) have been developed and adopted with the aim of simultaneous development of physical and technical abilities, together with increasing player compliance by increasing motivation to train.

Physiological (e.g. heart rate), movement (e.g. global positioning systems) and perceptual (e.g. perceived exertion) measures have been used to generate a comprehensive understanding of a players performance during SSGs training (Hill-Haas, Dawson, Impellizzeri, & Coutts, 2011). The effect of altering player number on SSGs training intensity, while at the same time holding other playing factors constant, has been well documented (Foster, Twist, Lamb, & Nicholas, 2010; Hill-Haas, Dawson, Coutts, & Rowsell, 2009; Mello & Navarro, 2008; Owen, Wong, McKenna, & Dellal, 2011; Rampinini et al., 2007; Sampaio et al., 2007). In general, games played with smaller numbers have elicited higher heart rate, blood lactate and perceptual responses when compared with games with a high number of players (Owen et al., 2011; Sampaio et al., 2007). However, when pitch area was increased relative to player number, a less pronounced effect was observed (Foster et al., 2010; Hill-Haas, Dawson, et al., 2009; Mello & Navarro, 2008; Rampinini et al., 2007), indicating that intensity is influenced by the amount of space each player has to move in.

Playing regime, including SSG duration and work to rest ratios, can be used to alter exercise intensity. Studies to date have utilised both interval training (Hill-Haas, Rowsell, Dawson, & Coutts, 2009; Rampinini et al., 2007), whereby periods of work are interspersed with periods of recovery, and continuous game formats (Hill-Haas, Rowsell, et al., 2009; Owen et al., 2011). Compared to continuous formats, intermittent SSGs produced more distance travelled at higher speeds, but elicited less physiological stimulus for aerobic fitness adaptation (Hill-Haas, Rowsell, et al., 2009). However, since a lack of studies exist examining altering regimes, drawing practical conclusions is difficult, and therefore further research in the area is warranted.

Using SSG rule modification, coaches can simulate the physiological intensity and technical and tactical requirements of competitive match play, to develop specific capabilities in their players. Research examining adult and adolescent players has shown changes to physiological load, time-motion characteristics and perceived effort as a result of rule modification (Gabbett, Jenkins, & Abernethy, 2010; Mello & Navarro, 2008). However, more studies are required to increase the body of knowledge on the effects of common rule changes used by coaches in practice with team sport athletes. Besides modification to rules, more generic conditioning exercise such as repeated sprints, can be added during SSGs to change the type of stimulus imposed on players and therefore influence subsequent training adaptation (Hill-Haas, Coutts, Dawson, & Rowsell, 2010).

Previous research comparing the respective long term effects of interval training and SSGs on performance are limited (Buchheit, Laursen, et al., 2009; Hill-Haas, Coutts, Rowsell, & Dawson, 2009; Impellizzeri et al., 2006; Reilly & White, 2004). Some researchers have reported improvements in various measures of aerobic fitness but no training type effect (Buchheit, Laursen, et al., 2009; Hill-Haas, Coutts, et al., 2009). More specifically, SSGs have been shown to be equally effective as generic aerobic training in developing $\dot{V}O_{2\ peak}$ (Impellizzeri et al., 2006) and other physiological parameters of aerobic fitness (Buchheit, Laursen, et al., 2009), but more effective at enhancing performance in sport-specific endurance capacity and actual match play (Buchheit, Laursen, et al., 2009; Hill-Haas, Coutts, et al., 2009; Impellizzeri et al., 2006).

To date, research investigating SSGs has focused primarily on quantifying the effects of various formats on aerobic fitness and performance in adult (Hoff, Wisloff, Engen, Kemi, & Helgerud, 2002; Impellizzeri et al., 2006; Owen et al., 2011; Rampinini et al., 2007) and adolescent (Buchheit, Laursen, et al., 2009; Castagna et al., 2007; Hill-Haas et al., 2010; Hill-Haas, Dawson, et al., 2009) athletes. There has been little consideration of younger athletes (i.e. < 14 years) (Foster et al., 2010; Katis & Kellis, 2009) who may participate in a variety of sports involving different skills, and may be less physically (Geithner et al., 2004) and technically (Chamari et al., 2005) developed than their older, more experienced counterparts. Indeed, SSGs provide an ideal training environment for young athletes to develop their technical skills, decision-making and problem solving skills, often under stressful physical loads, all of which are critical to the successful long term development of a young team sport athlete. Furthermore, most studies have adopted forms of SSGs that are closely matched to specific sports (Hill-Haas et al., 2011). It is important to quantify the physical and technical demands of a range of SSGs including non-sport specific formats, since these games incorporate essential skills that could be applicable to a wide range of team sports (e.g. rugby union, rugby league, basketball and netball). For young athletes in the early stages of their development, it may be considered that the most effective SSG is one that is physically demanding, but also allows players to maximise and refine fundamental technical skills and decision making abilities. Therefore, given the increasing popularity of SSGs in training, further experimental evidence investigating various game specifications is required to determine their benefits to aerobic performance in young team sport athletes.

1.2 Rationale of the Study and Thesis Aims

Training protocols to evaluate aerobic fitness in young athletes are limited in the current literature. Those that do exist have differed widely in terms of exercise type, duration, intensity and recovery period, making it difficult to draw conclusions on their effects and make practical applications accordingly. Furthermore, differences in training adaptation across maturation have been reported. As such, it would appear important to tailor aerobic exercise to the maturity status of the athlete involved to optimise development.

Many young athletes find adhering to traditional aerobic fitness training protocols difficult. Most often, a lack of enjoyment and experience with this type of exercise restricts their capacity to work at the high intensity levels required for successful adaptation. To address this, the use of SSGs to develop technical and tactical components and aerobic fitness concurrently has been proposed. However, research in to the efficacy of using SSGs in younger athletes is lacking. Indeed, it is not yet known what combination of game variables best suits young athletes, who are likely to be less technically and tactically developed than older, more mature athletes. Moreover, the application of a non sport-specific 'generic' SSG has received limited attention in the literature and may be applicable to a wide range of young athletes who participate in a number of different team sports.

It is likely that young athletes will respond better psychologically to a more motivating training stimulus than traditional aerobic conditioning methods. Small-sided games also provide an ideal environment for athletes to accumulate hours of technical skills training and an opportunity to develop decision-making and problem solving skills under stressful physical loads, both of which could be critical to the successful long term development of a team sport athlete. Thus, further research identifying the appropriate overload to bring about successful aerobic adaptation, while stimulating enjoyment and providing challenges specific to developmental requirements and across multiple training sessions, is warranted.

The overall purpose of this thesis was to investigate optimal training regimes to improve aerobic fitness in young male team sport athletes in New Zealand. Accordingly, the specific aims of this thesis are to:

1. Describe the natural development and trainability of aerobic fitness in children and adolescents with regard to maturity status and to review and quantify all training methods used to improve aerobic fitness and performance in young male team sport athletes.

2. Investigate the physiological and physical responses, movement characteristics and technical executions during a non sport-specific SSG in young male team sport athletes specific to:
    i. Player number and field size
    ii. Sport-specific SSG equivalents
    iii. Team selection strategy
    iv. Continuous and intermittent playing regimes
    v. Game rules
    vi. Inter-game generic conditioning exercise

3. Investigate the effects of SSGs and high-intensity interval training on aerobic fitness parameters and performance in young male team sport athletes.

1.3 Thesis Organisation

This doctoral thesis is intended to produce a cohesive body of work on optimising aerobic fitness development in young athletes. The thesis was structured in three stages including a review of the literature, investigation of the best SSG format for optimising aerobic fitness development, and the effects of SSG aerobic fitness training (Figure 1.1). It is comprised of one systematic literature review (Chapter 2), and five original experimental investigations, of which four are acute studies (Chapters 3-6) and one is a training study (Chapter 7). All studies have been submitted as stand-alone papers to international peer-reviewed journals at the time of thesis submission, some of which have been accepted for publication already or are undergoing second reviews. Each chapter is presented in the format of the journal for which it was written, but for consistency and ease of reference, all citations have been presented in APA format with a single bibliography at the end of the thesis.

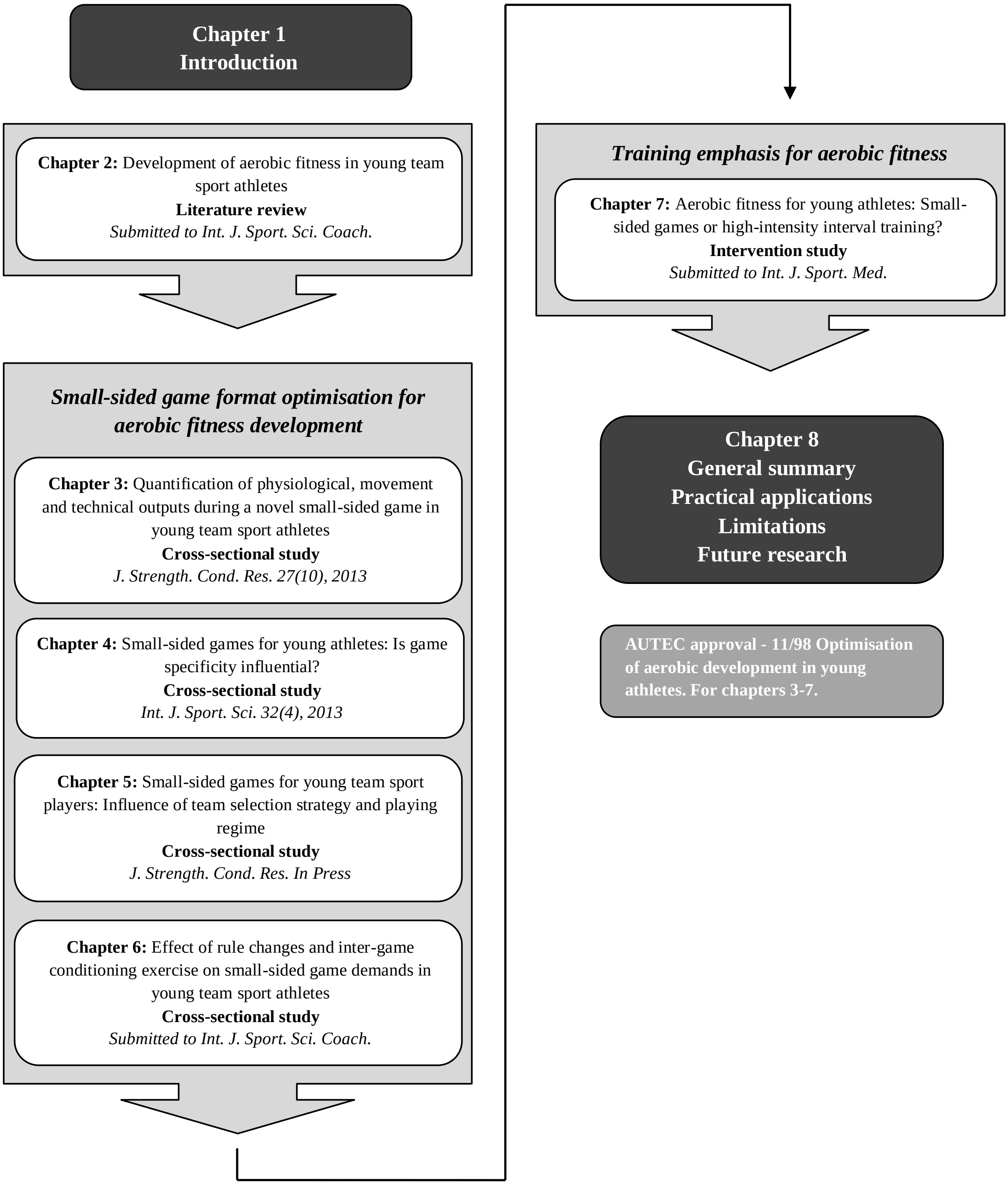


Figure 1.1 Thesis structure schematic

The literature review in this thesis (Chapter 2) considers the development and trainability of aerobic fitness in young athletes in a team sport context. Firstly, it reviews the literature with regards to maturation, developmental training stages and the natural development and trainability of aerobic fitness. It then reviews training regimes for developing aerobic fitness in young athletes aged between 9 and 17 years. Based on the findings, it then highlights appropriate training modes and loading parameters for implementation with young athletes during the different developmental stages identified. Subsequent chapters in this thesis focus on the limitations and recommendations presented in the literature review.

Chapters 3-6 comprise a series of studies that quantified and refined the playing parameters of a novel, non sport-specific SSG to maximise the physiological stimulus for aerobic adaptation in young male athletes. To this end, the studies were conducted in a progressive manner, where the findings of one study specifically informed the aim and methodology of the next. Given the importance of technical skill development in young team sport players, this was also a key consideration throughout these studies. Once the optimal SSG format was defined, a fully-controlled training intervention was conducted to compare the effects of the identified optimal SSG and high-intensity, intermittent running on aerobic fitness variables and physical performance (Chapter 7).

The final chapter of this thesis (Chapter 10) consists of a general discussion section including a summary of key findings, limitations and areas for future research. Given the applied intention of this research, a practical applications section is also provided to enable coaches and sport scientists to improve their training prescription. Overall, this thesis addresses questions relating to best practice in optimising aerobic fitness development in young team sport athletes.

1.4 Overview of Studies

A summary of each experimental study is provided below.

Study 1, Chapter 3

In this descriptive study, a novel non sport-specific SSG was implemented with young team sport players to gain insight into the physiological and perceptual responses, time-motion characteristics and technical executions associated with the game. In order to answer the thesis questions, playing number and field size were manipulated to assess the appropriateness of different formats for subsequent aerobic fitness training.

Study 2, Chapter 4

In this descriptive study, the same non sport-specific SSG as in Study 1 and a sport-specific SSG were implemented in young soccer players. The physiological and perceptual responses, time-motion characteristics and technical executions were compared to determine differences in game outputs and the suitability of each SSG for aerobic fitness training, accordingly.

Studies 3 and 4, Chapters 5 and 6

In these descriptive studies, different formats of the non sport-specific SSG were investigated, including manipulation of playing regime, team selection strategy, game rules and inter-game conditioning exercise, to further examine its effectiveness for physical and technical development of young team sport athletes, and to provide valuable practical applications for coaches.

Study 5, Chapter 7

In this intervention study, SSG training and high-intensity interval running training were investigated to determine their effects on aerobic fitness characteristics and a range of physical performance components in young team sport athletes.

1.5 Significance of Study

Suitable training regimes are required when working with young team sport athletes to optimise their physical and technical development. However, while training protocols need to be based on sound theory, they also need to be realistic and practical. This thesis contributes to the body of knowledge by determining optimal conditioning approaches for young athletes. The results provide valuable information that will assist our understanding of the best SSG regimes for aerobic fitness development and enable coaches to improve training and subsequent performance in their young athletes.

Chapter 2: Development of aerobic fitness in young team sport athletes

2.1 Introduction

An important component contributing to successful performance in many invasion team sports is a player's physical ability to repeatedly produce high-intensity intermittent bouts of exercise during games that typically last 60-120 min (Helgerud, Engen, Wisloff, & Hoff, 2001; Hoff et al., 2002; Loftin, Anderson, Lytton, Pittman, & Warren, 1996). The aerobic fitness status of an individual largely determines this ability due to its substantial role during recovery, which assists with delaying the onset of fatigue, allowing for high-intensity exercise to be sustained during play (Tomlin & Wenger, 2001). In addition, an increased aerobic capacity substantially influences a player's technical and tactical performance during a game by allowing them to make better choices under fatigue (Chamari et al., 2005). Therefore, approaches to develop aerobic fitness in athletes require specific consideration.

In young athletes, fluctuations in the rate of anatomical, neurological, muscular, metabolic and hormonal development occur (Naughton, Farpour-Lambert, Carlson, Bradney, & Van Praagh, 2000; Viru et al., 1999). These parameters likely play an important role in the ability to adapt to a specific training stimulus. To date, the most well-known model to include such physiological considerations, is the long term athlete development (LTAD) model (Balyi & Hamilton, 2004). The model attempts to balance training load and competition throughout childhood and adolescence. It suggests that through objective physiological assessment, e.g. peak height velocity (PHV), coaches can account for maturation rates for each athlete and relevant individual training programmes can be prescribed accordingly. Furthermore, based on physiological parameters linked to natural growth and maturation, the model indicates specific periods of accelerated and enhanced physical development termed "windows of trainability". Recently however, an absence of empirical evidence to support the LTAD model has resulted in much conjecture and debate surrounding its use (Ford et al., 2010). Specifically, controversy exists in the literature around the timing of the accelerated and decelerated periods of peak oxygen uptake relative to maturity status, or in fact whether or not they even exist (Baquet, Van Praagh, & Berthoin, 2003; Viru et al., 1999). Therefore at present, the application of “windows of trainability” by practitioners for the development of aerobic fitness is questionable.

More general descriptions of athlete development have been proposed (Bloom, 1985; Côté, Baker, & Abernethy, 2007). The developmental model of sports participation (DMSP) was proposed by Côté et al. (2007) based on retrospective studies of team sports (Baker, 2003; Baker, Cote, & Abernethy, 2003a, 2003b; Côté, 1999). The DMSP characterises development as a three-stage approach, with *sampling, specialisation* and *investment* broadly describing the process through which an athlete transitions. The different stages within the development process from beginner to elite level are based on changes in the type and amount of participation in sport activities, such as deliberate play, deliberate practice, and general and specific strength and conditioning, that are involved with training and competition (Ford et al., 2012). Although such a model may present an oversimplified representation of athlete development and transition (Gulbin, Weissensteiner, Oldenziel, & Gagne, 2013 (In Press)), it is based on recent evidence describing the types of activities young athletes engage in throughout their progression to an elite level. Therefore, the DMSP model provides a practicable framework that specific physiological components, such as aerobic fitness, can be incorporated and expanded within.

With this in mind, the purpose of this paper is to review the development of aerobic fitness in team sport athletes throughout male youth, defined as players between the ages of 9 and 17 years. The focus on males only is due to differences in timing and tempo of maturation between genders, and subsequent differences in physical and physiological characteristics from the onset of puberty (Geithner et al., 2004; Philippaerts et al., 2006). First, a brief review on the natural development and generic trainability of aerobic fitness in youth is provided which is important to understand when considering young athletes. Second, training programmes specifically aimed at developing aerobic fitness in team sport players are systematically reviewed to determine the most appropriate and effective training stimulus for a given development stage.

2.2 Determining maturity status of young athletes

Between the ages of 9 and 17 years, the biological development of an individual can vary considerably, in terms of timing and duration, compared to another athlete of the same chronological age (Iuliano-Burns, Mirwald, & Bailey, 2001; Krivolapchuk, 2011; Marshall & Tanner, 1970; Mirwald, Baxter-Jones, Bailey, & Beunen, 2002). Consequently, it is important to account for maturity status when investigating the development of young athletes (Malina, Bouchard, & Bar-Or, 2004). Moreover, monitoring physical and physiological changes due to maturation and training allow the responsiveness to various training stimuli to be determined. The most common clinical method to determine biological maturity uses plain X-ray of the left hand, wrist or knee (Malina et al., 2004) and has been used extensively to classify athletes according to their skeletal age (Carling, le Gall, Reilly, & Williams, 2009; Johnson, Doherty, & Freemont, 2009; Malina et al., 2000). However, the expensive cost and ethical issues of invasive measures need to be carefully considered in non-clinical situations. Alternatively, sexual maturity revealed by secondary sex characteristics, such as pubic hair development, has been used to determine maturation (i.e. Tanner staging) and found to be consistent with skeletal maturity (Tanner & Whitehouse, 1976). Nevertheless, this method requires physical examinations of participants by an experienced investigator which is also invasive and can be an expensive and time consuming process.

In a sporting context, cheaper and less invasive assessments of maturation, while still being accurate, are more appropriate. Accordingly, maturational status based on Tanner staging can be estimated via self-assessment questionnaires (Buchheit, Laursen, et al., 2009; Leone & Comtois, 2007), though this still requires administration by a qualified examiner and willingness by participants to engage in the process. Alternatively, a non-invasive, practical method of predicting years from peak height velocity (a maturity offset value), by using simple objective anthropometric measures, has been developed (Mirwald et al., 2002) and widely adopted (Malina et al., 2004; Philippaerts et al., 2006; Tønnessen, Shalfawi, Haugen, & Enoksen, 2011; Yague & De la Fruente, 1998). Peak height velocity (PHV) describes the point during maturation when the rate of growth in stature is at its maximum (Mirwald et al., 2002). Rather than chronological age, years from PHV is used to characterise changes in body size, body composition and performance relative to changes in height (Malina et al., 2004; Philippaerts et al., 2006). Maturity status can be expressed as pre-PHV (>1 year prior to PHV), mid-PHV (±1 year from PHV), and post-PHV (>1 year post PHV) and comparisons of any changes in physical capacity or performance made accordingly. Such an approach is an excellent method for classification of young team sport players when interpretation of physical tests is being conducted, but has limitations with extremely short athletes for their age (Malina et al., 2006). Also, the accuracy of PHV usually requires serial measurements for a numbers of years surrounding the occurrence of PHV and can only be used retrospectively.

2.3 Natural development of aerobic fitness in youth

The status and functioning of the respiratory, cardiovascular and metabolic systems combine to determine an individual's aerobic fitness. In exercise science, a number of measures can be determined to characterise an individual's aerobic ability, including work economy, lactate threshold (LT), oxygen uptake ($\dot{V}O_2$) kinetics and peak $\dot{V}O_2$ (Whipp & Mahler, 1980), with the latter being the most commonly used measure by which aerobic fitness is assessed (Naughton et al., 2000).

The natural development of $\dot{V}O_{2peak}$ during growth and maturation has been investigated with both cross-sectional (Krahenbuhl, Skinner, & Kohrt, 1985; Philippaerts et al., 2006; Washington, Vangundy, Cohen, Sognheiner, & Wolfe, 1988) and longitudinal (Binkhorst, De Jong-Van De Kar, & Vissers, 1984; Geithner et al., 2004; McMurray, Harrell, Bradley, Deng, & Bangdiwala, 2002; Rutenfranz et al., 1981; Sprynarova, Parizkova, & Bunc, 1987; Vanden Eynde, Vienne, Vuylsteke-Wauters, & Van Gerven, 1988) research designs. Absolute $\dot{V}O_{2peak}$ increases approximately 200 $ml \cdot min^{-1}$ per year prior to puberty (Rowland, 1997), and continues to increase until 16 years of age in males and 13 years of age in females (Malina et al., 2004; Mirwald & Bailey, 1986). The presence of a growth spurt in $\dot{V}O_2$ (i.e. a non-linear increase) similar to that for height has been indicated, with the estimated maximum rate of development in $\dot{V}O_2$ ($ml \cdot min^{-1}$ per year) occurring near the time of PHV (Geithner et al., 2004; Philippaerts et al., 2006). Following PHV, $\dot{V}O_{2peak}$ continues to increase in both sexes, with males having higher values than females at all ages (Geithner et al., 2004). These increases are predominantly attributed to changes in central mechanisms that occur with growth, including an increase in the size of the heart, lungs and muscles, and in blood volume (Rowland, 1997). Size-independent mechanisms, such as the activation of cellular aerobic enzymes (Eriksson, Gollnick, & Saltin, 1973; Geithner et al., 2004) and increases in circulating hormones (e.g. testosterone) (Rowland, 1997), have also been suggested to contribute to the increase in $\dot{V}O_{2peak}$ during growth. However, further research is needed to investigate how these mechanisms contribute to the natural development of aerobic fitness in youth specifically.

2.4 Development of aerobic fitness with training

Physical training of 3-4 sessions per week for 8-12 weeks has been shown to increase $\dot{V}O_{2peak}$ over and above the normal increase attributable to age and maturation by around 8 - 10% (Baquet et al., 2003). However, the response to aerobic training is conflicting, especially in pre-PHV children. In support of the proposed “window” for aerobic fitness development (i.e. after PHV onset) (Balyi & Hamilton, 2004), longitudinal studies have reported that $\dot{V}O_{2peak}$ increases only slightly prior to PHV, despite 3-4 years of prior training, and thus specific aerobic fitness training at prepubescent ages may not appreciably improve this component (Kobayashi, Kitamura, & Miura, 1978; Mirwald, Bailey, & Cameron, 1981). The reasons for this are not clear, but stroke volume is reported to be similar in trained and untrained prepubescent boys, suggesting a potential limitation is cardiac development prior to puberty (Hamilton & Andrew, 1976). In contrast, more recent studies have reported significant improvements in $\dot{V}O_{2peak}$ pre-PHV following training (Baquet, Berthoin, & Van Praagh, 2002; Baquet et al., 2010; Rowland, 1985). Differences in the activity history of participants, or in exercise protocol (i.e. intensity and duration), may have contributed to the discrepancies in findings between the studies. Therefore, it appears that aerobic performance can still be enhanced during the pre-PHV stage of development. Studies utilising participants at mid-PHV are limited but indicate increases in $\dot{V}O_{2peak}$ in males following training (Mahon & Vaccaro, 1989b; Rowland, Varzeas, & Walsh, 1991). Improvements in aerobic performance during this stage of development have been related to changes in hormone secretion during maturation (Naughton et al., 2000).

The discrepancy in the literature in terms of whether a “window” does in fact exist is likely due to a lack of well-monitored training protocols that are similar in their exercise type, duration, intensity and recovery period. Furthermore, much of the evidence for the development of aerobic fitness in young individuals is based on cross-sectional studies, which restricts inferences due to a lack of causality. To assess changes in aerobic fitness during growth and the influence of training concurrently, further research involving training studies at specific PHVs and across different maturity levels, together with well-planned longitudinal studies, are required. In the meantime, aerobic fitness should be actively developed throughout childhood and adolescence rather than aligning exercise prescription to any specific “windows of opportunity” (Ford et al., 2010; Shepard, 2002).

2.5 Systematic analysis of methods to increase aerobic fitness in young team sport athletes

The aim of this systematic review was to depict the current practices used by young team sport players to enhance aerobic performance. Subsequently, findings were used to guide an evidence-based model for aerobic fitness development. This analysis is relevant to the context of team sport athlete development and relative to growth and maturation. All young athletes in reviewed studies were categorised into sampling (6-12 years), specialisation (13-15 years) and investment years (>16 years). This classification, which has been used in a previous systematic review (Rumpf, Cronin, Pinder, Oliver, & Hughes, 2012), corresponds approximately to the years prior to PHV, around PHV and post-PHV respectively (Malina et al., 2004).

2.5.1 Search strategies and inclusion criteria

The following electronic data bases were searched multiple times between September 1st, 2012 and October 31st, 2012: PubMed, Google Scholar, Sport Discus, and Medline, for articles published between the years of 1950 and 2013. The following keywords were used in various combinations during the electronic searches: *team sport, athletes, youth, child, aerobic, fitness, aerobic power, high-intensity, small-sided games, interval, running.* References were also identified from textbooks of sports science and aerobic and anaerobic training. The identified articles, manuscripts and thesis reference sections were also scanned to identify further studies. The studies were required to be written in English. Final selections were based on team sport populations under the age of 18 years old (n = 14).

2.5.2 Data analysis

To evaluate the magnitude of the training effects, percent change [(Post Xmean – Pre Xmean) ÷ Pre Xmean *100] was calculated for each dependent variable. To account for the variance of the change within and between groups, effect size (ES) calculations [(Post Xmean – Pre Xmean) ÷ PreSD] were also included. The standardised effects were classified as: trivial (< 0.2), small (0.2-0.6), moderate (0.6-1.2), large (1.2-2.0), very large (2.0-4.0) and extremely large (>4.0) (Hopkins, Marshall, Betterham, & Hanin, 2009). The main training variable of interest was $\dot{V}O_{2peak}$, but other aerobic fitness variables and performance outcomes were included when reported in the studies. The results of the analysis were discussed according to different factors thought to influence training adaptations in youth team sport players, such as development stage/maturity, training duration, training sessions and training modes.

2.5.3 Athlete characteristics

A total of 361 team sport athletes were investigated including 326 as part of intervention groups in 13 separate studies and 35 athletes acting as controls in 3 studies (Table 2.1). Chronological age ranged from 11 – 17 years, with an estimated mean age of 15.5 ± 1.6 years. Maturation was directly (Tanner stages) assessed in three studies and indirectly (PHV) assessed in one study. The non-inclusion of maturity assessment in many studies of young athletes made it impossible to differentiate between participants across studies based on biological development. Instead, as outlined in the DMSP, athletes were categorised by chronological age into development stages of sport participation (Côté et al., 2007). Accordingly, 20 athletes were in their sampling years (Vamvakoudis, Vrabas, Galazoulas, & Stefanidis, 2007), 171 in their specialisation years (Bogdanis, Ziagos, Anastasiadis, & Maridaki, 2007; Buchheit, Laursen, et al., 2009; Chamari et al., 2005; Gabbett, 2006a; Hill-Haas, Coutts, et al., 2009; Manna, Khanna, & Dhara, 2011; Safania, Alizadeh, & Nourshahi, 2011; Sperlich et al., 2011) and 135 in their investment years (Ferrari-Bravo et al., 2008; Gabbett, 2006a, 2006b; Impellizzeri et al., 2006; Impellizzeri et al., 2008; Tønnessen et al., 2011). A high proportion of the athletes investigated were playing their chosen sport at the junior elite level (80%), whereas the remaining athletes played at junior club level (14%) or were recreational players (6%). Weekly training and playing time was 7.5 hours per week for sampling aged athletes, and ranged from 3.3-10 hours per week for specialisation athletes and from 3.3-14 hours per week for investment athletes. Considerable variation existed in weekly training and playing time between studies and in contrast to previous research, demonstrated no obvious increase with development stage (Côté et al., 2007).

Table 2.1. Systematic review of effects of generic training on aerobic fitness variables in young team sport players

Study	Sport / level	Age (y)	Dev Phase (maturity marker)	Baseline VO_{2peak} ($ml \cdot kg \cdot min^{-1}$)	St-dur (w)	S/W	Intervention	Training phase	Performance test (s)	% change	ES
Sperlich et al. (2011)	Soccer / junior elite	13.5 ± 0.4 (n = 9)	Specialisation (No)	55.1 ± 4.9	5	3-4	HIIT = 4-12 [30-240 s @ 90-95% HR_{peak} / 30-180 s @ 50-60% HR_{peak} PR]	Mid-season	VO_{2peak}	↑7.0	0.77
Sperlich et al. (2011)	Soccer / junior elite	13.5 ± 0.4 (n = 9)	Specialisation (No)	55.3 ± 4.3	5	3-4	MXD = 2-6 [6-30 min @ 50-70% HR_{peak} / 0-5 min PR]	Mid-season	VO_{2peak}	↑2.0	0.26
Gabbett et al. (2008)	Rugby League / junior elite	14.1 ± 0.2 (n = 14)	Specialisation (No)	43.3 ± 1.3 (predicted)	10	3	MXD = 6 weeks CONT + 4 weeks RS & HI - various [10-40 m / 15-30 s PR] + various [45-90 s ‘hard’ / 45-180 s PR]	Pre-season	pVO_{2peak}	↑12.7	4.2**
Hill-Haas et al. (2009)	Soccer / junior elite	14.6 ± 0.9 (n = 10)	Specialisation (Yes - PHV)	60.2 ± 4.6	7	2	MXD = AP, HIT, RS, COD, & SL / 1-3 min PR]	Pre-season	VO_{2peak} ($ml \cdot kg \cdot min^{-1}$) VO_{2peak} ($ml \cdot kg^{0.75} \cdot min^{-1}$) MSFT YYIRT1	↑2.0 ↑2.4 ↑3.1 ↑21.9	0.26 0.29 0.53 1.51**
Buchheit et al. (2009)	Handball / junior club	15.7 ± 0.9 (n = 17) Tanner (III – V)	Specialisation (Yes -Tanner)	NR	10	2	HIIT = [6-12 min of 15 s @ 95% V_{IFT} / 15 s PR]	Pre-season	V_{IFT} $Tlim_{100\%VIFT}$ $Tlim_{95\%VIFT}$ $Tlim_{90\%VIFT}$	↑5.6 ↑36.1 ↑11.6 ↑17.1	0.56* 0.68* 0.30 0.54
Safania et al. (2011)	Soccer / recreational	15.7 ± 0.7 (n = 10)	Specialisation (No)	34.0 ± 1.4 (predicted)	6	3	HIIT = 4 [4min @ 70-95% HR_{peak} / 3min @ 60-70% HR_{peak}] & 30 min ‘competitive play’	Pre-season	pVO_{2peak}	↑28.0	6.9***
Manna et al. (2011)	Hockey / junior elite	14 – 15.9 (n = 30)	Specialisation (No)	54.6 ± 2.8	12	5	MXD = HIT+ CONT + TECH	Pre-season & in-season	VO_{2peak} (W8) VO_{2peak} (W12)	↑3.1 ↓0.4	0.61* 0.07
Tonnessen et al. (2011)	Soccer / junior elite	16.4 ± 0.9 (n = 10)	Investment (Yes – PHV)	NR	10	1	RS = 2-5 [4-5 x 40m @ 95-100% / 1.5-2 min: 10 min]	Pre-season	MSFT 10 x 40 m RSA (s)	↑5.0 ↓2.2	0.5 -0.70**

Tonnessen et al. (2011)	Soccer / junior elite	16.4 ± 0.9 (control = 10)	Investment (Yes – PHV)	NR			Regular soccer training	Pre-season	MSFT 10 x 40 m RSA (s)	↔ ↓1.1	 -0.32*
Gabbett et al. (2008)	Rugby League / junior elite	16.9 ±0.3 (n = 21)	Investment (No)	43.4 ± 1.1 est	10	3	MXD = 6 weeks CONT + 4 weeks RS & HI - various [10-40 m / 15-30 s PR] + various [45-90 s 'hard' / 45-180 s PR]	Pre-season	eVO_{2peak}	↑4.1	1.6
Gabbett (2006b)	Rugby League / junior elite	16.9 (16.7-17.1) (n = 36)	Investment (No)	46.3 (45.0 – 47.7)	14	2	MXD = various [10-40 m / 15-30 s PR] + various [45-90 s 'hard' / 45-180 s PR] + Skill-based conditioning games	Pre-season	eVO_{2peak}	↑8.6*	No SD?
Impellizzeri et al. (2006)	Soccer / junior elite	17.2 ± 0.8 (n = 15)	Investment (Yes – Tanner)	57.7 ± 4.2	12	2	HIIT = 4 [4min @ 90-95% HR_{peak} / 3min @ 60-70% HR_{peak}]	Pre-season & in-season	VO_{2peak} (w4) VO_{2peak} (w12) VO_2 @ LT (w4) VO_2 @ LT (w12)	↑7.4 ↑8.3 ↑8.0 ↑12.9	1.21 1.35 0.95 1.53
Bravo et al. (2008)	Soccer / junior elite	17.3 ± 0.6 (n = 13)	Investment (No)	52.8 ± 3.2	12	2	HIIT = 4 [4min @ 90-95% HR_{peak} / 3 min AR]	In-season	VO_{2peak} YYIRT1 RSA	↑6.6 ↑12.5 ↔	1.1** -
Bravo et al. (2008)	Soccer / junior elite	17.3 ± 0.6 (n = 13)	Investment (No)	55.7 ± 2.3	12	2	RS = 3 [6 x 40 m sprints / 20 s PR (4 min PR)]	In-season	VO_{2peak} YYIRT1 RSA	↑5.0 ↑28.1 ↑2.1	1.2* - 0.76*
Impellizzeri et al. (2008)	Soccer / junior club	17.8 ± 0.6 (n = 13)	Investment (Yes – Tanner)	NR	4	2-3	HIIT = 4 [4min @ 90-95% HR_{peak} / 3 min active jog]	Post-season	VO_{2peak} YYIRT1	↑4.0 ↑12.0	0.23** 0.75***

N = Number of Participants; St-dur = Study Duration; S/W = Intervention sessions per week; VO_{2peak} = peak oxygen uptake; pVO_{2peak} = predicted peak oxygen uptake; eVO_{2peak} = estimated peak oxygen uptake; LT= Lactate threshold; C_R = Running Economy; % Change = Percent Change; ES = Effect Size; Tanner = Tanner Staging System for Sexual Maturity; PHV = peak height velocity; NR = Not Reported; HIIT = High intensity interval training; RS = repeated sprint; CONT = continuous training; PR = passive recovery; AR = active recovery; YYIRT1 = Yo-Yo intermittent recovery test level 1; RSA = Repeated sprint ability; MXD = missed training; MSFT = multi-stage fitness test; * Indicates Significance ($p \leq 0.05$) change following training; ** Indicates Significance ($p \leq 0.01$) change following training; *** Indicates Significance ($p \leq 0.001$) change following training; ↔ Indicates no change

Table 2.2. Systematic review of effects of sport-specific training on aerobic fitness variables in young team sport players

Study	Sport	Age (y)	Dev Phase (maturity marker)	BL VO_{2peak} ($ml \cdot kg \cdot min^{-1}$)	St-dur (W)	S/w	Intervention	Training phase	Performance test(s)	% change	ES
Vamvakoudis et al. (2007)	Basketball/ junior elite	11.5 (n = 20)	Sampling (Yes - Tanner)	51.4 ± 3.9	78	6	MXD = 90 min [drills 8-10 min @ 75-85% HR_{peak} + 40-45 min @ 50-60% HR_{peak}, instructional games, & jumping & sprinting]	All	VO_{2peak} (W52) ($ml \cdot kg \cdot min^{-1}$) VO_{2peak} (W78) ($ml \cdot kg \cdot min^{-1}$)	↑3.6** ↑11.1**	
Vamvakoudis et al. (2007)	Basketball / junior elite	11.5 (controls = 18)	Sampling (Yes - Tanner)	NR	78	2-3	MXD = 40 min [soccer, basketball & volleyball games in PE class @ 40-50% HR_{peak}]	All	VO_{2peak} (W52) ($ml \cdot kg \cdot min^{-1}$) VO_{2peak} (W78) ($ml \cdot kg \cdot min^{-1}$)	↓0.7 ↑0.9	
Chamari et al. (2005)	Soccer / junior elite	14.0 ± 0.4 (n = 18)	Specialisation (No)	65.3 ± 5.0	8	2	Dribbling track = 4 [4min @ 90-95% HR_{peak} / 3min @ 60-70% HR_{peak}] & SSGs = 4 [4 min 4 vs. 4 @ 90-95% HR_{peak} / 3min @ 60-70% HR_{peak} AR]	Mid-season	VO_{2peak} ($ml \cdot kg \cdot min^{-1}$) VO_{2peak} ($ml \cdot kg^{0.75} \cdot min^{-1}$) Hoft test	↑7.5 ↑12.0 ↑9.6	1.0 1.0 1.2**
Hill-Haas et al. (2009)	Soccer / junior elite	14.6 ± 0.9 (n = 9)	Specialisation (Yes – PHV)	59.3 ± 4.5	7	2	SSGs = 3-6 [7-13 min 2 vs. 2 – 6 vs. 6 various rules]	Pre-season	VO_{2peak} ($ml \cdot kg \cdot min^{-1}$) VO_{2peak} ($ml \cdot kg^{0.75} \cdot min^{-1}$) MSFT YYIRT1	↓0.67 ↓0.60 ↓0.7 ↑17.1	-0.09 -0.11 -0.07 0.74**
Bogdanis et al. (2007)	Basketball / junior elite	14.7 ± 0.5 (n = 10)	Specialisation (Yes - Tanner)	52.3 ± 1.4	4	5	MXD = 120 min [drills, exercises, 5 vs. 5 full & half court games]		VO_{2peak} ($ml \cdot kg \cdot min^{-1}$)	↑4.9	0.22*
Bogdanis et al. (2007)	Basketball / junior elite	14.7 ± 0.5 (n = 10)	Specialisation (Yes - Tanner)	52.5 ± 1.3	4	5	MXD = 120 min [drills, exercises, 5 vs. 5 full & half court games & circuits]		VO_{2peak} ($ml \cdot kg \cdot min^{-1}$)	↑4.9	0.22*
Bogdanis et al. (2007)	Basketball / junior elite	14.7 ± 0.5 (control = 7)	Specialisation (Yes - Tanner)	NR			No training		VO_{2peak} ($ml \cdot kg \cdot min^{-1}$)	↔	
Buchheit et al. (2009)	Handball / junior club	15.7 ± 0.9 (n = 15) Tanner (III – V)	Specialisation (Yes – Tanner)	NR	10	2	SSGs = 2-4 [150-240 s 4 vs. 4]	Pre-season	V_{IFT} $Tlim_{100\%VIFT}$ $Tlim_{95\%VIFT}$ $Tlim_{90\%VIFT}$	↑6.5 ↑26.5 ↑5.5 ↑39.4	0.8* 0.62* 0.14 0.93*

Safania et al. (2011)	Soccer Recreational	15.7 ±0.7 (n = 10)	Specialisation (No)	34.2 ± 1.6 est	6	3	SSGs = 4 [4 min various 2 vs. 2 – 4 vs.4 / 3 min PR] + 30 min 'competitive play'	Pre-season	eVO_{2peak}	↑25.4	5.4***
Impellizzeri et al. (2006)	Soccer junior elite	17.2 ±0.8 (n = 14)	Investment (Yes – Tanner)	55.6 ± 3.4	12	2	SSGs = 3 vs. 3 – 5 vs. 5 various rules]	Pre-season & in-season	VO_{2peak} (W4) VO_{2peak} (W12) VO_2 @ Tlac (W4) VO_2 @ Tlac (W12)	↑6.4 ↑7.1 ↑7.1 ↑10.8	0.88 0.98 0.69 1.04

N = Number of Participants; St-dur = Study Duration; S/W = Intervention sessions per week; VO_{2peak} = peak oxygen uptake; pVO_{2peak} = predicted peak oxygen uptake; eVO_{2peak} = estimated peak oxygen uptake; LT= Lactate threshold; C_R = Running Economy; % Change = Percent Change; ES = Effect Size; Tanner = Tanner Staging System for Sexual Maturity; PHV = peak height velocity; NR = Not Reported; HIIT = High intensity interval training; RS = repeated sprint; CONT = continuous training; PR = passive recovery; AR = active recovery; YYIRT1 = Yo-Yo intermittent recovery test level 1; RSA = Repeated sprint ability; MXD = missed training; MSFT = multi-stage fitness test; * Indicates Significance ($p \leq 0.05$) change following training; ** Indicates Significance ($p \leq 0.01$) change following training; *** Indicates Significance ($p \leq 0.001$) change following training; ↔ Indicates no change

2.5.4 Training mode

The specific details of training mode for each study are presented in Tables 2.1 and 2.2. Two main training modes were implemented to improve aerobic fitness in young players: generic training and sport-specific training. Generic training (Table 2.1) involved non-sport specific exercise and included either high-intensity interval training (HIIT), repeated sprint training, continuous moderate intensity exercise, or a combination of the three (mixed training). Briefly, HIIT was the most popular training mode (six interventions), followed by repeated sprints (two interventions), and continuous running (one intervention). Four studies investigated the effects of mixed training modes on aerobic performance (Gabbett, 2006a, 2006b; Hill-Haas, Coutts, et al., 2009; Manna et al., 2011). Mixed exercise protocols included the performance of drills and activities involving technical skills (Manna et al., 2011) and skill-based games (Gabbett, 2006b). Alternatively, sport-specific training (Table 2.2) involved the implementation of purposely designed exercise tasks involving a ball. These included small-sided games (SSGs; five interventions), exercise drills and activities (four interventions) and a game-specific circuit (one intervention).

With respect to developmental phase, HIIT interventions were implemented more often with athletes while in their investment years compared to athletes in their specialisation years (40% vs. 20%, respectively). Mixed exercise training regimes and SSGs were more frequently implemented with specialisation aged athletes compared to investment athletes (35% vs. 20% and 28% vs. 10%, respectively), and repeated sprint training was only used with athletes in their investment years. The sole study that investigated players in their sampling years implemented a sport-specific mixed training intervention.

2.5.5 Effects of generic training on aerobic fitness and performance

The effect of generic training on aerobic performance in young team sports players was considered in 10 studies. Generic training is defined as exercise modes not involving the technical skills of the sport for which training is focused towards. In a series of six studies investigating HIIT, players undertook 5-12 weeks of exercise, 2-4 times per week. Interventions lasted between 15 s and 4 min, with 4-24 repetitions at work intensities corresponding to 90-95% of peak HR, separated by 15 s – 3 min of active or passive recovery. Four of the seven studies implemented 4 x 4 min of running at 90-95% of peak HR separated by 3 min of active recovery at 60-70% of peak HR, which has previously been shown as an effective regime to increase aerobic fitness and soccer specific performance in adults (Helgerud et al., 2001). Although the magnitude of the changes varied considerably, all training interventions that controlled for intensity were effective at improving $\dot{V}O_{2peak}$ by 4 to 28% (Buchheit, Laursen, et al., 2009; Ferrari-Bravo et al., 2008; Impellizzeri et al., 2006; Impellizzeri et al., 2008; Safania et al., 2011; Sperlich et al., 2011). When analysis was restricted to studies involving high level players (junior elite), the variability reduced considerably to 4 to 7.4%. The study by Impellizzeri et al. (2006) reported the largest improvement in $\dot{V}O_{2peak}$ (7.4%) after a four week preseason training regime, when players may have been deconditioned, especially since no further increase in $\dot{V}O_{2peak}$ was reported following an additional eight weeks of training during the competitive season. In contrast, $\dot{V}O_2$ at lactate threshold was improved following both the pre-season and competitive season training (8% and 4.9%, respectively), suggesting a lack of sensitivity of $\dot{V}O_{2peak}$ to HIIT training in this cohort. Importantly, three of the six studies that implemented HIIT protocols also examined the influence of HIIT on intermittent shuttle test performance. In this regard, total running distance increased by 12 to 32.5% in the Yo-Yo intermittent recovery test

(YYIRT) level 1 (Ferrari-Bravo et al., 2008; Impellizzeri et al., 2008), and final running velocity was increased by 5.6% in the 30-15 intermittent fitness test (Buchheit, Laursen, et al., 2009), suggesting that multiple physiological variables are associated with intermittent shuttle running.

Other generic training studies have adopted alternative approaches including repeated sprint protocols between 95 and 100% intensity (Ferrari-Bravo et al., 2008; Tønnessen et al., 2011). Ferrari-Bravo et al. (2008) reported a significant improvement in the $\dot{V}O_{2peak}$ of junior elite soccer players following three sets of 6 x 40 m maximal sprints, twice a week for 12 weeks. Using a similar protocol involving 2-5 repetitions of 4-5 x 40 m sprints at 95-100% intensity, but of different frequency and duration (i.e. once per week for 10 weeks), Tonnessen et al. (2011) showed an increase (5%; ES = 0.5) in the distance covered during the multi-stage fitness test (MSFT or Beep Test) and predicted $\dot{V}O_{2peak}$ accordingly, in junior elite soccer players. A control group that participated in regular soccer training showed no change in MSFT performance (Tønnessen et al., 2011) suggesting that game play alone is insufficient to enhance aerobic fitness measures.

Four studies implemented mixed training regimes. Mixed training is defined as training that involves various combinations of continuous moderate-intensity running, HIIT, repeated sprinting, and technical drills and activities within the same session. Three of the four studies reviewed reported moderate to large increases in $\dot{V}O_{2peak}$ of 3.1 to 12.7% (Gabbett, 2006a, 2006b; Manna et al., 2011). The remaining study only showed a small increase (2%; ES = 0.26) in $\dot{V}O_{2peak}$ (Hill-Haas, Coutts, et al., 2009). Specifically, Hill-Haas et al. (2009) implemented a combination of coach-prescribed HIIT, repeated sprinting and change of direction drills without stipulating specific exercise intensity. As a result, minimal exercise was performed above 90% HR_{peak}, which was attributed as to why limited improvement in $\dot{V}O_{2peak}$ was observed. Finally, with 2-6 repetitions of 6-30 min of moderate-intensity running (50-70% of HR_{peak}), Sperlich et al. (2011) reported a small increase in $\dot{V}O_{2peak}$ (2.0%; ES = 0.26) in junior elite soccer players. Unfortunately, the individual impact of each exercise mode during mixed training regimes is impossible to determine, making it difficult to derive specific implications for practice.

In summary, small to very large improvements in $\dot{V}O_{2peak}$ following generic training interventions have been reported independently of training frequency, duration and length of intervention. Periods of high intensity effort appear to be a key factor in training design to obtain a substantial increase in $\dot{V}O_{2peak}$. Aerobic performance during intermittent shuttle running can be improved by various generic training methods and without a concomitant increase in $\dot{V}O_{2peak}$.

2.5.6 Effects of sport-specific training on aerobic fitness and performance

Sport-specific training is defined as exercise regimes that involve similar technical and/or tactical tasks of the athletes' chosen sport. To date, eight studies (Table 2.2) have investigated sport-specific training in young team sports players, with SSGs and ball-based drills and activities. Study duration and session frequency ranged from 4-78 weeks and 2-6 sessions per week respectively. Moderate to very large increases in $\dot{V}O_{2peak}$ were reported following SSG training regimes in junior elite (Buchheit, Laursen, et al., 2009; Chamari et al., 2005; Impellizzeri et al., 2006) and recreational players (Safania et al., 2011). Buchheit et al. (2009) also reported a moderate increase in the final running velocity on the 30-15 intermittent fitness test in junior club handball players. Large variation in game methodology existed across studies (e.g. duration and player numbers ranged from 2.5 to 13 min and 2 vs. 2 to 6 vs. 6, respectively), but SSGs were selected based on previous descriptive research indicating that exercise intensity responses would be high, and therefore sufficient stimulus for aerobic adaptation would be achieved (Buchheit, Lepretre, et al., 2009). In contrast, when Hill-Haas et al. (2009) implemented SSG training that was prescribed by a soccer coach to increase the external validity of their study, no change in $\dot{V}O_{2peak}$ was reported. However, despite no change in $\dot{V}O_{2peak}$, an increase in the YYIRT level one (17%) was reported (Hill-Haas, Coutts, et al., 2009), suggesting that intermittent shuttle running performance is determined by multiple physiological characteristics.

Sport-specific, mixed training protocols have been implemented in two previous studies (Bogdanis et al., 2007; Vamvakoudis et al., 2007). Increases in $\dot{V}O_{2peak}$ were reported following exercise regimes consisting of 78 weeks of drills and instructional games (11.1%) (Vamvakoudis et al., 2007) and four weeks of exercise drills and SSGs (4.9%; ES = 0.22) (Bogdanis et al., 2007) in junior elite basketball players. A control group that performed 'normal' basketball training during the same intervention period showed no change in $\dot{V}O_{2peak}$ (Vamvakoudis et al., 2007). Additionally, a sport-specific training circuit in combination with SSGs was examined (Chamari et al., 2005). Junior elite soccer players completed one 4 vs. 4 SSG session and one circuit session of equal intensity (4 x 4 min at 90 - 95% HR_{peak}, separated by 3 min running at 60-70% HR_{peak}) each week for eight weeks. Increases were reported in $\dot{V}O_{2peak}$ relative to bodyweight (7.5%; ES = 1.0), allometrically scaled $\dot{V}O_{2peak}$ (12%; ES = 1.0), and in the distance covered during the Hoff Dribbling Track Test (9.6%; ES = 1.2) (Chamari et al., 2005).

In summary, improvements in peak $\dot{V}O_2$ and intermittent shuttle running performance were reported following various sport-specific aerobic fitness training protocols. Small-sided games were the most beneficial method of training implemented, but limited variation in this type of training has been investigated to date. Additional studies are warranted to further explore the use of SSGs to develop aerobic fitness in team sports, particular for younger (>14 years) athletes.

2.6 An evidence-based model of aerobic fitness development in young team sport players

Based on the available literature, a proposed model for the development of aerobic fitness in young team sport players is presented (Figure 2.1). It is intended to provide coaches with a strategic approach to develop aerobic fitness in their players. Specifically, the model is designed to provide clear and simple prescriptive guidelines based on scientific theory and evidence, while at the same time allowing room for situational and sport-specific needs. The model proposes the most beneficial types of aerobic exercise based on developmental stage. However, it is by no means exclusive and coaches should use these guidelines keeping individual and situational variability in mind. To interpret it, the appropriate pathway (read from left to right) should be taken based firstly on the chronological age of the athlete, and then on whether the desired $\dot{V}O_{2peak}$ level of athletes has been reached.

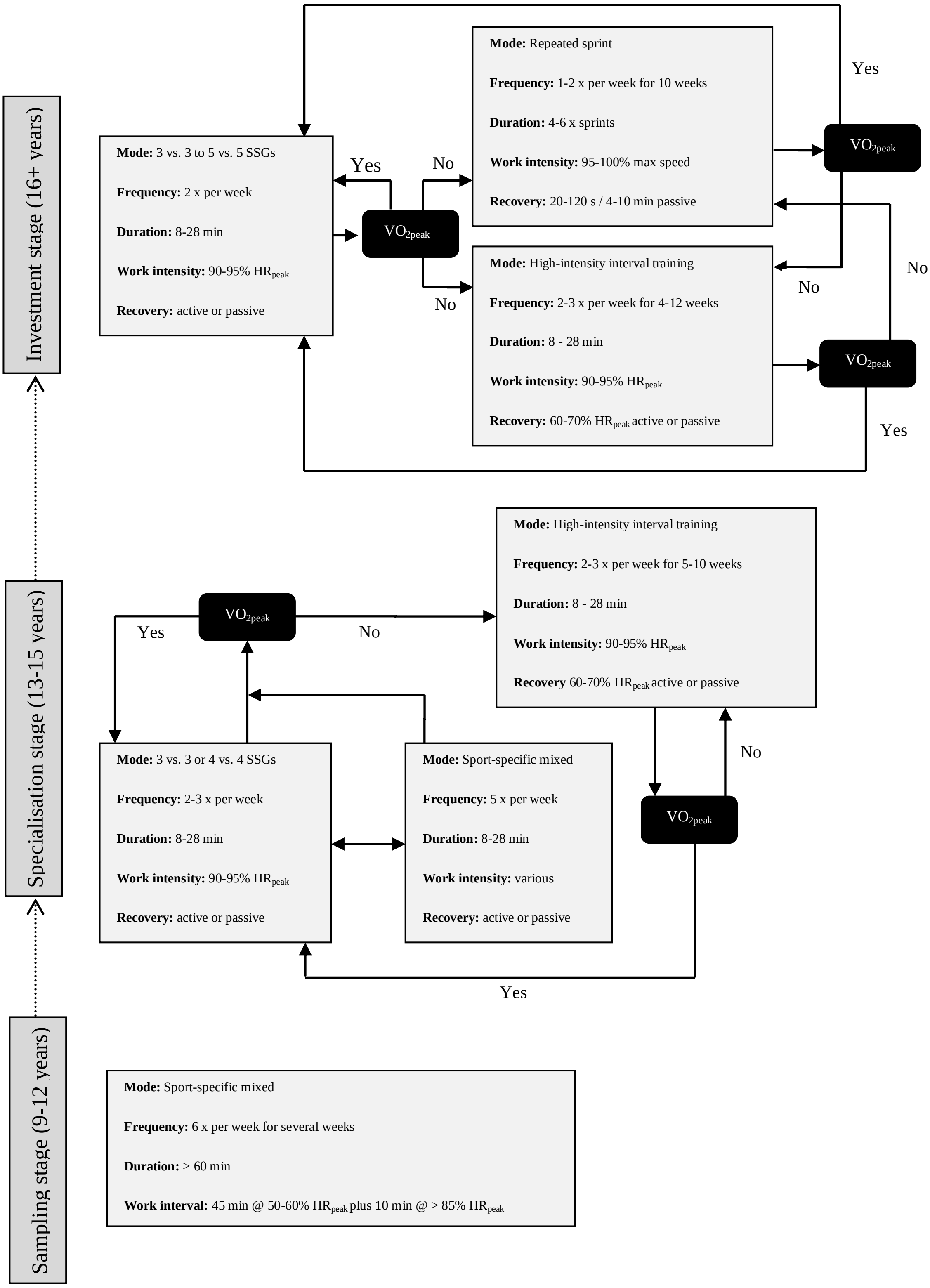


Figure 2.1. A proposed evidence-based model for aerobic fitness development in young team sport players. SSGs, small-sided games.

2.6.1 The sampling stage (ages 9-12 years)

The main focus during the sampling stage is participation in a number of activities with an overriding emphasis on enjoyment (Côté et al., 2007). Generic aerobic fitness training regimes consisting of regular running, cycling or swimming, continuous or interval exercise, have been shown to increase $\dot{V}O_{2peak}$ by 8-10% in this age bracket (Baquet et al., 2003). However, to maximise a player's development, the importance of early engagement and deliberate play in game-based activities has been reported (Ford, Ward, Hodges, & Williams, 2009). Unfortunately, research investigating the trainability of aerobic fitness for young team sport players in their sampling years is limited to only a single study by Vamvakoudis et al. (2007) (Table 2). Vanvakoudis et al. (2007) reported a substantial improvement in the $\dot{V}O_{2peak}$ of junior elite basketball players by implementing drills and instructional games, six times per week for 52 weeks. Each session lasted for at least 60 min with 40-50 min of training time spent at 50-60% HR_{peak}, but a short period of moderate-intensity exercise (i.e. 10 min between 75-85% HR_{peak}) was included. Based on these findings and the overall objectives of the sampling years, regular participation in moderate-intensity, sport-specific mixed training is proposed (Figure 2.1). However, further research is required to examine aerobic fitness trainability in team sport populations during this developmental stage. More specifically, activities to be implemented in this development stage should be playful and fun and experimental designs examining the best use of SSGs would seem appropriate. Furthermore, consideration of game characteristics and structure given the level of technical skill of the athletes involved is critical.

2.6.2 The specialisation stage (ages 13-15 years)

The overall focus of the specialisation stage is mastery of individual, sport specific skills, and other sport-specific activities (Côté et al., 2007). The majority of training time is dedicated to deliberate practice, with some time spent in deliberate play activities. With this in mind, aerobic fitness training that provides for the simultaneous development of technical and tactical skills would seem advantageous. Accordingly, and given the clear effects presented in this review (Buchheit, Laursen, et al., 2009; Chamari et al., 2005) (Table 2.2), training built on a foundation of SSGs and complemented with mixed, sport-specific training interventions would appear advantageous. Small-sided games consisting of 3 vs. 3 or 4 vs. 4 player formats, performed on large areas 2-3 times per week, have been shown to provide sufficient intensities for successful aerobic adaptation, as well as improving intermittent shuttle test performance (Buchheit, Laursen, et al., 2009; Chamari et al., 2005; Hill-Haas, Coutts, et al., 2009) (Figure 2.1). Work phases during SSGs should be carefully monitored to achieve intensities of 90-95% HR_{peak}, and be separated by passive rest or active recovery at 60-70% HR_{peak} (Buchheit, Laursen, et al., 2009; Chamari et al., 2005). There is no clear influence of the length of programme, but training blocks of at least eight weeks appear necessary for developing $\dot{V}O_{2peak}$. Alternatively, training interventions involving a mix of ball drills, activities and circuits have been shown to also be effective at improving aerobic fitness (Bogdanis et al., 2007; Chamari et al., 2005) (Table 2.2) and therefore valuable for use during the specialisation stage (Figure 2.1).

Despite recent evidence depicting the advantages of SSGs compared to HIIT (Buchheit, Laursen, et al., 2009), limitations with this type of exercise have also been suggested (Hill-Haas et al., 2011). Limited research delineating the effects of prescriptive variables on player’s physiological and physical responses during various SSG formats and codes presents a clear need for more cross-sectional training studies, especially in young athletes, to determine the most effective stimulus for development of aerobic fitness. Furthermore, since SSGs require a combination of technical and tactical abilities, decision making and physical exertion, it seems that concurrent abilities may be required to achieve sufficient stimulus for subsequent aerobic adaptation (Hill-Haas et al., 2011). Consequently, lower-skilled players and/or those with poor game intelligence and understanding may profit less from SSG training. Similarly, for more experienced, highly-skilled players, who through effective decision making may be capable of reducing the intensity at which they are required to work during SSGs (Hill-Haas et al., 2011). Therefore, the relationship between aerobic fitness, technical skill, game intelligence and attainable exercise intensity should be investigated further in future research.

Because aerobic fitness may not always be improved to the desired level using SSGs or sport-specific mixed training regimes (Hill-Haas, Coutts, et al., 2009), and to account for individual variability in exercise intensity (Hill-Haas et al., 2011), utilisation of HIIT during the specialisation stage of player development is worthwhile. Indeed, less variability in exercise intensity has been shown with generic interval training compared to SSGs, presumably because individual player workloads can be accurately prescribed and maintained throughout training (Buchheit, 2008; Helgerud et al., 2007). High-intensity interval training is effective at increasing aerobic fitness and intermittent shuttle performance during this development stage (Buchheit, Laursen, et al., 2009; Sperlich et al., 2011). This form of training should be prescribed 2-3 times per week for blocks of 5-10 weeks. Work period can vary in duration from 30 s to 4 min, but intensity should be consistently high (90-95% HR_{peak}). This can be accomplished by using the final running velocity of the 30-15 intermittent fitness test to set individual running distances (Buchheit, 2008) or controlled with HR monitoring technology (Helgerud et al., 2007). Rest intervals should involve active (i.e.

60-70% HR_{peak}) or passive recovery (see Table 2.1) (Buchheit, Laursen, et al., 2009; Safania et al., 2011; Sperlich et al., 2011). Once players adapt to the training stimulus and aerobic fitness is increased, SSGs may again become the exercise mode that is prioritised (i.e. refer to arrows on Figure 2.1).

2.6.3 The investment stage (ages 16+ years)

The investment stage is characterised by the acquisition of expertise and during which deliberate practice as a team is the best use of the training hours (Bloom, 1985; Ericsson, Krampe, & Tesch-Romer, 1993). The main focus is on improving performance, with an emphasis on competitive activities. However, despite players entering young adulthood during this stage, some may not yet be fully physically developed and therefore overall training volume should be considered. Impellizzeri et al. (2006) reported a moderate improvement (6.4%) in $\dot{V}O_{2peak}$ after SSG training in junior elite soccer players. Since both physical and technical outcomes can be gained concurrently during SSGs training, this method should be prioritised during the investment years (Figure 2.1). However, to ensure desired outcomes are met, a high level of prescription should be of upmost importance. Team numbers can vary from 3 vs. 3 to 5 vs. 5, but games should be performed in large areas relative in size to the total number of players involved (Hill-Haas, Dawson, et al., 2009; Impellizzeri et al., 2006). Games consisting of 4 bouts of 4 min at high-intensity (90-95% HR_{peak}) separated by 3 min of active recovery (60 – 70% HR_{peak}) have been shown to be effective (Impellizzeri et al., 2006). However, further studies are required to elucidate other SSG variables and work:rest ratios effective at eliciting appropriate stimulus to improve aerobic fitness.

In the case of shortfalls in SSGs training to meet individual aerobic fitness targets, or to maintain aerobic fitness in-season, “top up” sessions involving HIIT and/or repeated sprint training are recommended. Performance of HIIT should be completed 2-3 times per week, for blocks of 4-12 weeks, at similar durations suggested for SSGs above. Work bouts should be performed at high-intensity (90-95% HR_{peak}) and separated by either active or passive recovery (Ferrari-Bravo et al., 2008; Impellizzeri et al., 2006; Impellizzeri et al., 2008). Alternatively, repeated sprint training blocks could be performed 1-2 times per week for 10-12 weeks. More specifically, four to six 40 m sprints should be completed at 95-100% of maximum effort, separated by 20 s to 2 min of passive recovery. Sprint blocks should be repeated 2-5 times, interspersed with passive rest lasting 4-10 min in duration (Ferrari-Bravo et al., 2008; Tønnessen et al., 2011).

2.7 Conclusion

Given current evidence on natural development of aerobic fitness and trainability, aerobic fitness should be actively developed in team sport players throughout their development, rather than aligning exercise to specific periods of maturation. However, based on a range of studies investigating aerobic fitness in young team sport players, the current review has highlighted particular training modes and loading parameters appropriate for implementation during the different developmental stages. In general, sport-specific training programmes should be prioritised throughout development to increase the opportunity for concurrent physical and technical development. However, training must be accurately prescribed using specific game variables to ensure the desired adaptations are achieved. Because of the longitudinal and dynamic nature of players' development over several years, aerobic fitness should be monitored carefully and short-term interventions prescribed with the long term physiological, technical and tactical skill objectives in mind. There is an apparent need for more descriptive training studies, particularly involving SSGs, to further assist in optimising aerobic fitness development alongside useful technical and tactical attributes in young team sport athletes.

Chapter 3: Quantification of physiological, movement and technical outputs during a novel small-sided game in young team sport athletes

3.1 Introduction

The aerobic capacity of young team sport players substantially influences their technical performance and tactical choices (Chamari et al., 2005). Therefore careful consideration of the most appropriate training approaches, accounting for maturation and skill status, is required to optimise their physical and technical development. Traditionally, training methods for aerobic fitness development have included repeated, high-intensity, intermittent bouts (Buchheit, Laursen, et al., 2009; Helgerud et al., 2007) or long continuous steady state efforts (Baquet et al., 2010; Helgerud et al., 2007). However, while these training approaches may be effective and tolerated by adults, they may be less-effective and impractical for younger individuals. Unique challenges exist when prescribing training regimes to young athletes and attempting to maximise enjoyment to ensure adherence and motivation to train.

In recent years, there has been an increased focus on the potential use of small sided games (SSGs) to improve a range of competencies of athletes, including aerobic fitness. Small sided games provide an ideal environment for athletes to develop their technical skills, decision-making and problem solving skills often under stressful physical loads; all of which are critical to the successful long term development of a young team sport athlete. Therefore, it is possible that children will respond better to SSGs than traditional aerobic conditioning methods if sufficient intensity can be achieved. Indeed, most studies to date have attempted to quantify the acute physiological responses and time-motion responses most related to SSG regimes, but these have been limited to either adults (>18 years) (Hoff et al., 2002; Impellizzeri et al., 2006; Little & Williams, 2006; Owen et al., 2011; Rampinini et al., 2007) or youth (14 – 18 years) aged athletes (Buchheit, Laursen, et al., 2009; Castagna et al., 2007; Hill-Haas et al., 2010; Hill-Haas, Dawson, et al., 2009) with little consideration of younger athletes (<14 years), who may be less physically (Geithner et al., 2004) and technically developed (Chamari et al., 2005) than their older counterparts. Furthermore, research to date has predominantly reported the acute physiological responses to SSGs in soccer (Casamichana & Castellano, 2010; Castagna et al., 2007; Da Silva et al., 2011; Dellal, Lago-Penas, Wong, & Chamari, 2011; Fanchini et al., 2011; Hill-Haas et al., 2010; Hill-Haas, Coutts, Rowsell, & Dawson, 2008; Hill-Haas, Coutts, et al., 2009; Hill-Haas, Dawson, et al., 2009; Hill-Haas, Rowsell, et al., 2009; Hoff et al., 2002; Kokiu, Asci, Kocak, Alembaroglu, & Dundar, 2011; Little & Williams, 2006; Mello & Navarro, 2008; Owen et al., 2011; Rampinini et al., 2007) with only limited consideration of SSGs that require control of possession with the hands (Buchheit, Laursen, et al., 2009; Foster et al., 2010; Gabbett, 2006b, 2012; Gabbett et al., 2010), especially in young athletes. It is important to quantify the physical demands of a range of SSG formats since ‘general’ catch and pass games incorporate basic taught skills that could be applicable to a wide range of team sports, if shown to be sufficiently demanding in young athletes.

In adult and youth aged athletes, SSGs played with smaller numbers, while relative pitch area remained constant, have elicited higher heart rates, blood lactate and perceptual responses when compared with games of higher numbers (Foster et al., 2010; Hill-Haas, Dawson, et al., 2009; Mello & Navarro, 2008; Rampinini et al., 2007). However, research examining altering player number during SSGs in young athletes (i.e. > 14 years) is limited and presents conflicting results. Katis and Kellis (2009) reported higher heart rate values in young soccer players during 3 vs. 3 (87.6% HR_{peak}) versus 6 vs. 6 (82.8% HR_{peak}) SSGs. In contrast, Foster et al. (2010) reported no significant difference in heart rate intensity between 4 vs. 4 (88.1% HR_{peak}) and 6 vs. 6 (89.3% HR_{peak}) games of “off-side” touch in young rugby league players. Clearly, further research is warranted to better understand the physiological effects of SSGs on young athletes. Furthermore, it is not yet known how varying player number influences the time-motion characteristics during non-soccer SSGs in this age group.

In addition to physical demands of SSGs, the execution and involvement with technical aspects of the game are important for skill development. Indeed, it may be considered that the most effective SSG for young athletes is one that is physically demanding, but also allows players to maximise and refine technical skills and decision making abilities. Surprisingly however, very few studies have reported the effects of varying external factors on technical skill execution during SSGs in young athletes (Katis & Kellis, 2009). Specifically, Katis and Kellis (2009) reported a significantly higher number of technical actions performed by players during 3 vs. 3 soccer SSGs when compared to 6 vs. 6 games. It is unknown how such technical outputs are influenced by player number during a more generic catch and pass game, relevant to a number of team sports (rugby union, rugby league, basketball and netball). Clearly, further research is warranted to better understand the interaction between physiological demands and technical outputs during a variety of types of SSGs in young players. Therefore, the aim of this study was to quantify the physiological responses, time-motion characteristics and technical outputs associated with a novel non sport-specific SSG in young team sport players.

3.2 Methods

3.2.1 Experimental approach to the problem

A cross-over, descriptive design was used in the study which lasted 3 weeks. All participants completed a multi-staged incremental treadmill run to determine peak oxygen uptake ($\dot{V}O_{2peak}$) and peak heart rate (HR_{peak}) and thereafter, on six separate occasions, participated in various SSG formats at the same time of the day, differentiated by player numbers and size of playing area (Table 3.1). A 1 week training period was used to familiarise participants with testing procedures, the SSG formats, as well as to assess each player in terms of their aerobic fitness, technical skill and game intelligence so that players could be allocated into balanced

SSG teams. Players were selected on the same team against the same opponents as often as possible.

3.2.2 Subjects

Twelve young male team sport players (mean ± SD: age,13.0 ± 0.3 years, height, 157.4 ± 4.9 cm, body mass, 47.0 ± 5.0 kg) participated in the study. Their maturation (-0.8 ± 0.4 years) was assessed as time from peak height velocity (PHV) using a non-invasive and practical method based upon anthropometric variables (Mirwald et al., 2002). All participants were recreationally trained and involved in at least two training sessions per week, plus a game. All participants and their parents (or guardians) were informed of the procedures and were required to give written informed consent and assent respectively. Approval from the institutional ethics committee for experimentation involving human subjects was gained prior to the commencement of the study.

3.2.3 Procedures

3.2.3.1 Incremental treadmill running test

Peak oxygen uptake ($\dot{V}O_{2peak}$) was determined during an incremental treadmill running test on a motorised treadmill (PowerJog, Birmingham, UK). The protocol of Armstrong et al. (Armstrong, Welsman, Nevill, & Kirby, 1999) was adopted. Briefly, after a 3 min warm-up at 6 $km \cdot hr^{-1}$ and 1% gradient, the treadmill speed was set at 8 $km \cdot hr^{-1}$ for the initial 3 min stage and increased to 10 $km \cdot hr^{-1}$ for the next stage. Thereafter, treadmill speed was held constant at 10 $km \cdot hr^{-1}$ and the gradient increased by 2.5% every 3 min until the participant reached volitional exhaustion. Participants were verbally encouraged to provide a maximal effort during the final stages of the test. Throughout the test pulmonary gas exchange was measured using a metabolic cart (Parvo TrueOne, UT, USA) which was calibrated for gas and volume prior to each test using alpha grade gases and known volumes. The $\dot{V}O_{2peak}$ was defined as the highest 30 s average $\dot{V}O_2$ attained during the test. Heart rate was monitored using short-range telemetry (Polar s610, Kemplele, Finland) and the HR_{peak} determined.

3.2.3.2 Small-sided games – Bucketball

Bucketball is a two-sided game during which the main objective is to score a goal in the opposing team's bucket (Figure 3.1). Running with the ball is permitted and it may be passed from the hands, player to player, in any direction. The team with the ball maintains possession until the ball is dropped, goes out of play or a bucket is scored. To score, the player must be outside of the bucket circle (Figure 3.1). After a goal is scored, play resumes by the team that conceded the goal from the top of their bucket circle. Passes may be intercepted and possession may be stolen from the player with the ball by the opposition dislodging it from their hands however the attacking player cannot be held in any way by the defender. In this study, for a goal to be validated all players had to be positioned inside the oppositions half when the shot was made. Additional balls were placed along the side-lines of the playing area to ensure play resumed quickly after the ball went out of play.

Participants competed in various formats of bucketball, on separate days, by varying the player numbers, including 3 vs. 3, 4 vs. 4 and 6 vs. 6 formats. Game duration was 16 min of continuous play and the playing area was 25 x 30m, 30 x 40m and 35 x 49m for 3 vs. 3, 4 vs. 4 and 6 vs. 6 games respectively (Hill-Haas, Dawson, et al., 2009; Little & Williams, 2006; Owen et al., 2011). Players performed each SSG two times (6 games total), and games were played in random order. All games were played outdoors on a dry grass surface in temperate conditions (16 Deg C, 50% rH).

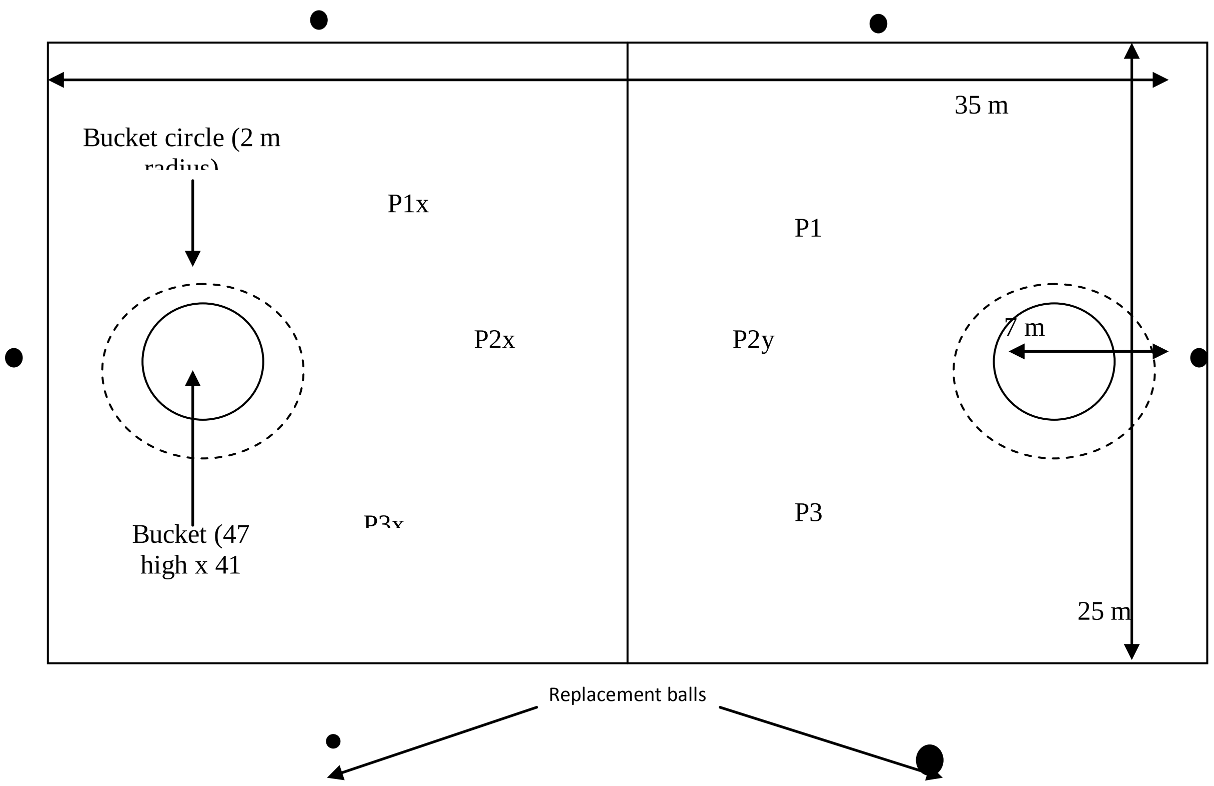


Figure 3.1 - Bucketball set-up and play dimensions for 3 vs. 3 format

Table 3.1 – Summary of small-sided games and formats

	Bucketball		
Rules	• No goalkeepers • Game is played with a size 4 handball • Unlimited number of steps with ball • Ball can be 'stolen' from players hands • Possession lost when ball is dropped, goes out of play or a bucket is scored		
Variables			
Player number	3 vs. 3	4 vs. 4	6 vs. 6
Game duration (min)	16 continuous		
Playing area size (m)	25 x 35	30 x 40	35 x 49
Bucket size (h x d) (cm)	47 x 41		
Bucket circle (r) (cm)	200		

3.2.4 Heart rate monitoring

The heart rate (HR) of each player was recorded during each SSG at 5 s intervals using radiotelemetry (VX Sport 220, Visuallex Sport International, Wellington, New Zealand). The mean (HR_{mean}) and HR_{peak} of all SSGs were determined. Relative exercise intensity of each SSG was expressed as percent HR_{peak} (as determined from the incremental test) and classified into 4 intensity zones: zone 1 (<75% HR_{peak}), zone 2 (75-84% HR_{peak}), zone 3 (85-89% HR_{peak}), and zone 4 (>90% HR_{peak}) (Gore, 2000).

3.2.5 Time-motion characteristics

Each player wore a portable global positioning system (GPS) unit (VX Sport 220, Visuallex Sport International, Wellington, New Zealand) to determine time-motion characteristics during all SSGs. The GPS system sampled at 4 Hz and provided speed and distance data.

Speed data was classified into 4 zones: walking (0-6.9 km·hr^{-1}), jogging (7-12.9 km·hr^{-1}), cruising (13-17.9 km·hr^{-1}), and sprinting (>18 km·hr^{-1}) (Hill-Haas, Rowsell, et al., 2009). GPS technology measuring at a frequency of 5Hz has been shown to offer a valid and reliable way of measuring distance and movement speed by players involved in team sports (Jennings, Cormack, Coutts, Boyd, & Aughey, 2010).

3.2.6 Psychophysical variables

Ratings of perceived exertion (RPE) were determined using the 6-20 linear Borg scale (Borg, 1982) at the completion of each SSG. Players were asked to base their perceived exertion on the entire game rather than at the time of rating. Instructions for RPE were given to participants during the SSG familiarisation sessions and anchored at 19 of the Borg 15-category scale following the final stage (i.e. volitional exhaustion) of the maximal treadmill test. The typical error of RPE for SSGs has been shown to be 1-2 units (Hill-Haas et al., 2008).

3.2.7 Technical skill executions

All SSGs were recorded using a high-speed digital video camera (Cannon G11, Tokyo, Japan). Post-game notation analysis was undertaken to determine each player's skill executions during each game. This method has previously been described as reliable (Kelly & Drust, 2009) The following executions were quantified by an experienced technical analyst: number of possessions, number of catches and passes, successful and unsuccessful catches and passes, and goals scored. A successful pass was defined as one that was either caught or able to be caught by a player on the same team as the player who made the pass.

3.3 Statistical Analyses

Data are presented as means ± SD. To make assumptions about true (population) values of the effect of different small sided games formats on physiological variables, time-motion characteristics and skill executions, the uncertainty of the effect was expressed as 90% confidence limits and as likelihoods that the true value of the effect represents substantial change. An effect was deemed unclear if its confidence interval overlapped the thresholds for substantiveness, meaning that the effect could be substantially positive and negative. The chances that the true (population) differences are substantial were assessed using 0.2 standardised units (change in mean divided by the between subject SD) and expressed as both percentages and qualitatively, using practical inferences (Hopkins, 2006b).

3.4 Results

3.4.1 Physical and perceptual characteristics

Table 3.2 shows HR response, time spent in different heart rate zones and RPE during bucketball. A likely substantial true difference in $\%HR_{peak}$ was shown between the 3 vs. 3 and 4 vs. 4 games (86%) as well as between the 3 vs. 3 and 6 vs. 6 games (92%). A likely substantial true difference was also shown in time spent above 90% HR_{peak} between 3 vs. 3 and 4 vs. 4, and 3 vs. 3 and 6 vs. 6 games (85% and 88%, respectively). There was no difference between the various bucketball game formats for RPE (Table 3.2).

3.4.2 Time-motion characteristics

Table 3.2 shows the distance travelled at different speed zones during bucketball. There was no true difference between the various bucketball game formats for total distance (TD). Total distance travelled at 13 – 17.9 $km \cdot hr^{-1}$ was greater during 6 vs. 6 than 3 vs. 3 games (very likely substantial true difference, 97%). Total distance above 18 $km \cdot hr^{-1}$ was less during 3 vs.

3 than both 6 vs. 6 (likely substantial true difference, 92%) and 4 vs. 4 games (likely substantial true difference, 81%). There was also a tendency for players to travel more of their TD at 0 – 6.9 $km \cdot hr^{-1}$ during 3 vs. 3 compared to 4 vs. 4 games (89%, Table 3.2).

3.4.3 Technical Outputs

Table 3.3 shows the technical outputs completed during three different formats of bucketball. Total possessions and number of catches, passes and shots were all higher in 3 vs. 3 compared with 4 vs. 4 and 6 vs. 6 games. The number of successful passes and catches was not different between games, however 3 vs. 3 allowed for more successful shots than 6 vs. 6 games (very likely substantial true difference, 96%, Table 3.3).

Table 3.2 - Technical skill executions during SSGs

Technical skill	3 vs. 3	4 vs. 4	6 vs. 6
Total possessions	25.5 ± 7.8	16.2 ± 4.9[a]	14.7 ± 5.2[a]
Total catches	21.3 ± 5.4	13.6 ± 4.1[a]	14.6 ± 5.0[c]
Successful catches (%)	93.5 ± 11.6	96.3 ± 4.1	95.6 ± 6.1
Total passes	17.8 ± 6.6	12.9 ± 4.3[c]	11.7 ± 5.0[c]
Successful passes (%)	89.3 ± 7.5	83.6 ± 10.6	84.3 ± 12.3
Total shots	7.0 ± 2.8	2.7 ± 2.5[a]	2.7 ± 2.0[a]
Successful shots (%)	54.7 ± 19.9	39.4 ± 23.1	31.4 ± 33.1[c]

[a] = Most likely substantial true difference from 3 vs. 3

[c] = Very likely substantial true difference from 3 vs. 3

Table 3.3 – Physiological and perceptual responses, and time-motion characteristics during SSGs

	Game Format				Chances that the true differences are substantial*		Game Format				Chances that the true differences are substantial*		Game Format				Chances that the true differences are substantial*	
	3 vs. 3	4 vs. 4	Difference; ±90% CL	Effect size; ±90% CL	%	Qualitative	3 vs. 3	6 vs. 6	Difference; ±90% CL	Effect size; ±90% CL	%	Qualitative	4 vs. 4	6 vs. 6	Difference; ±90% CL	Effect size; ±90% CL	%	Qualitative
$\%HR_{peak}$ (bpm)	88.3 ± 4.3	85.9 ± 4.9	-2.4; ±2.4	-0.53; ±0.54	86	Likely	88.3 ± 4.3	85.9 ± 3.2	-2.5; ±1.9	-0.54; ±0.42	92	Likely	85.9 ± 4.9	85.9 ± 3.2	0.0; ±1.9	-0.01; ±0.42	22	Unlikely
TD (m)	1414 ± 98	1429 ± 147	15.5; ±63.0	0.11; ±0.43	35	Possibly	1414 ± 98	1427 ± 106	13.6; ±49.6	0.09; ±0.34	29	Possibly	1429 ± 147	1427 ± 106	-1.9; ±65.3	-0.01; ±0.44	23	Unlikely
TD at 0 – 6.9 $km \cdot hr^{-1}$ (m)	678 ± 73	639 ± 55	-38.6 ±35.3	-0.61; ±0.56	89	Likely	678 ± 73	655 ± 43	15.8; ±31.4	-0.36; ±0.58	57	Possibly	639 ± 55	655 ± 43	-22.8; ±36.9	0.25; ±0.50	69	Possibly
TD at 7 – 12.9 $km \cdot hr^{-1}$ (m)	585 ± 80	580 ± 104	-5.2: ±43.5	-0.05; ±0.42	27	Possibly	585 ± 80	544 ± 62	-41.9; ±33.7	-0.40; ±0.32	86	Likely	580 ± 104	544 ± 62	-36.7; ±39.0	-0.35; ±0.37	76	Likely
TD at 13 – 17.9 $km \cdot hr^{-1}$ (m)	137 ± 65	188 ± 90	51.0; ±43.4	0.63; ±0.54	91	Likely	137 ± 65	195 ± 89	58.4; ±36.9	0.72; ±0.46	97	Very Likely	188 ± 90	195 ± 89	7.4; ±40.2	0.09; ±0.50	16	Unlikely
TD at > 18 $km \cdot hr^{-1}$ (m)	11 ± 15	21 ± 28	10.2; ±8.7	0.35; ±0.30	81	Likely	11 ± 15	34 ± 45	23.3; ±20.6	0.80; ±0.71	92	Likely	21 ± 28	34 ± 45	13.1; ±22.6	0.45; ±0.78	71	Possibly
Time spent below 75% HR_{max} (s)	40 ± 99	75 ± 87	35.4; ±36.9	0.27; ±0.28	67	Possibly	40 ± 99	54 ± 65	14.7; ±36.3	0.11; ±0.28	67	Possibly	75 ± 87	54 ± 65	-20.8; ±37.5	-0.16; ±0.29	57	Possibly
Time spent at 75 - 84% HR_{max} (s)	185 ± 184	295 ± 221	109.3; ±118	0.56; ±0.60	85	Likely	185 ± 184	265 ± 192	79.9; ±72.0	0.41; ±0.37	83	Likely	295 ± 221	265 ± 192	-29.6; ±106.0	-0.15; ±0.54	44	Possibly
Time spent at 85 - 89% HR_{max} (s)	233 ± 146	236 ± 90	3.2; ±85.6	0.03; ±0.67	32	Possibly	233 ± 146	267 ± 83	34.0; ±92.7	0.27; ±0.74	57	Possibly	236 ± 90	267 ± 83	30.8; ±52.4	0.24; ±0.42	57	Possibly
Time spent above 90% HR_{max} (s)	503 ± 309	356 ± 314	-148.1; ±153.9	-0.53; ±0.55	85	Likely	503 ± 309	370 ± 223	-132.7; ±112.2	-0.48; ±0.40	88	Likely	356 ± 314	370 ± 223	14.4; ±114.5	0.05; ±0.41	27	Possibly
RPE	15.2 ± 1.2	15.0 ± 0.9	-0.3; ±0.9	-0.19; ±0.64	49	Possibly	15.2 ± 1.2	14.8 ± 0.9	-0.5; ±0.9	-0.35; ±0.65	65	Possibly	15.0 ± 0.9	14.8 ± 0.9	-0.2; ±0.2	-0.16; ±0.18	34	Possibly

HR = heart rate; TD = total distance; RPE = rating of perceived exertion

3.5 Discussion

Small-sided games are commonly used as a specific training modality for enhancing aerobic fitness in a variety of team sport players (Buchheit, Laursen, et al., 2009; Impellizzeri et al., 2006). Recent evidence indicates that by manipulating game variables to achieve appropriate overload, successful adaptation can occur (Buchheit, Laursen, et al., 2009; Hill-Haas, Dawson, et al., 2009; Impellizzeri et al., 2006). However the majority of research to date has used youth (14-18 years) (Casamichana & Castellano, 2010; Castagna et al., 2007; Dellal, Lago-Penas, et al., 2011; Foster et al., 2010; Hill-Haas et al., 2010; Hill-Haas, Dawson, et al., 2009; Hill-Haas, Rowsell, et al., 2009; Little & Williams, 2006; Owen et al., 2011) or adult (Fanchini et al., 2011; Gabbett, 2006b; Gabbett et al., 2010; Hoff et al., 2002; Mello & Navarro, 2008; Rampinini et al., 2007) populations, and soccer as the main sport (Casamichana & Castellano, 2010; Castagna et al., 2007; Da Silva et al., 2011; Dellal, Lago-Penas, et al., 2011; Fanchini et al., 2011; Hill-Haas et al., 2010; Hill-Haas, Coutts, et al., 2009; Hill-Haas, Dawson, et al., 2009; Hill-Haas, Rowsell, et al., 2009; Hoff et al., 2002; Kokiu et al., 2011; Little & Williams, 2006; Mello & Navarro, 2008; Owen et al., 2011; Rampinini et al., 2007). Consequently, little is known about other types of SSG formats that best suit younger athletes (<14 years) and who may participate in a variety of sports involving upper and lower body skills. Hence, the main objective of this study was to quantify the physiological responses and time-motion characteristics associated with a non sport-specific SSG in young team sport players. The main finding of this study was that bucketball produced a high level of physiological stimulus, and therefore may be useful to train aerobic fitness in young athletes. In addition, when player numbers were increased, with a relative increase in player area, a greater effect was seen on physiological workloads than on either time-motion characteristics or perceptual response.

3.5.1 Physiological and Perceptual Responses

This study examined three different formats of a non sport-specific SSG in young athletes aged at their peak height velocity. Heart rate intensities found in the present study were similar to previous studies examining 3 vs. 3 SSGs in soccer players (Dellal, Chamari, et al., 2011; Fanchini et al., 2011; Katis & Kellis, 2009; Little & Williams, 2006; Mello & Navarro, 2008; Rampinini et al., 2007). The mean percent HR_{peak} responses during 3 vs. 3 bucketball were larger than both 4 vs. 4 and 6 vs. 6 game formats (Table 3.2). In addition, a likely substantial true difference was shown in time spent above 90% HR_{peak} between 3 vs. 3 and 4 vs. 4, and 3 vs. 3 and 6 vs. 6 games (85% and 88%, respectively). A likely explanation for the difference in heart rate response between the three bucketball SSG formats was the occurrence of a greater number of ball possessions and greater overall individual involvement when player numbers were reduced (Table 3.3). Indeed, it has been previously shown that time in possession increases energy expenditure compared to running without the ball in soccer players (Reilly & Ball, 1984). This effect is consistent with previous research examining the effect of altering player number, relative to playing area, on SSG training intensity in youth and adult soccer and rugby league (Foster et al., 2010; Hill-Haas, Dawson, et al., 2009; Mello & Navarro, 2008; Rampinini et al., 2007). Since high heart rates are important for improving aerobic fitness during training (Helgerud et al., 2007; Hoff et al., 2002), these findings indicate that fewer player numbers during a non sport-specific SSG may be more suitable for successful aerobic fitness adaptation in young athletes.

We observed no difference in percent HR_{peak} between the 4 vs. 4 and 6 vs. 6 bucketball SSGs (Table 3.2). This finding concurs with one previous study examining SSGs in young rugby league players (Foster et al., 2010), but disagrees with the results of previous research investigating altering player number during SSGs in older athletes (Foster et al., 2010; Hill-Haas, Dawson, et al., 2009). This finding may reflect a difference in tactical ability between young and more experienced older players. Inferior tactical awareness by young players may cause them to self-restrict the area in which they work and focus too intently on the ball rather than the events occurring elsewhere associated with getting free. Accordingly, higher numbers of players all looking for the ball at once is likely to reduce player movement and subsequent game intensity. With experience, increased tactical awareness may in fact negate this issue as the ability to move effectively off the ball and find space to receive a pass may improve.

Ratings of perceived exertion are considered a good global indicator of exercise intensity when compared with HR during game-specific exercise in adolescent and adult players (Hill-Haas, Dawson, et al., 2009; Rampinini et al., 2007) and have be shown to be highest with decreasing numbers of players in SSGs (Hill-Haas, Dawson, et al., 2009; Little & Williams, 2006; Rampinini et al., 2007). However, the present study reports similar RPE across all bucketball SSG formats (Table 3.2), suggesting that perception of effort by young athletes during SGGs may not be influenced by player number and may therefore not be an accurate indicator of game intensity in this age group. It is possible that young athletes do not have the necessary experience to distinguish between relatively small changes in exercise intensity during SSGs. More research is required involving appropriate RPE anchoring and familiarisation procedures to investigate this area further.

3.5.2 Time-motion characteristics

The GPS data from this study demonstrate that despite no apparent difference in total distance travelled between game formats, there was a likely chance (89%) that players travelled more total distance at 0-6.9 km·hr^{-1} in the 3 vs. 3 compared to 4 vs. 4 game format. Moreover, players travelled less total distance at higher running speeds (i.e. above 13 km·hr^{-1}) during the 3 vs. 3 format compared to 4 vs. 4 and 6 vs. 6 games (Table 3.2). Similar results have been demonstrated when 2 vs. 2 and 4 vs. 4 SSGs in adolescent soccer players were compared (Hill-Haas, Dawson, et al., 2009). These authors reported a significant difference in distance travelled at 0-6.9 km·hr^{-1} between the two game formats and suggested less absolute pitch space available for high speed running as a possible contributing factor to their findings. It has also been suggested that increased possession during SSGs, resulting from less players involved, requires players to slow down their running speeds for better control of technical outputs (Hill-Haas, Dawson, et al., 2009; Owen et al., 2011). Indeed, the present study provides further evidence for this by demonstrating that greater distance travelled at lower speeds during 3 vs. 3 compared to 4 vs. 4 and 6 vs. 6 games may have resulted from the higher technical output required. Individual possessions, passes and shots were all higher in 3 vs. 3 compared to 4 vs. 4 and 6 vs. 6 games (Table 3.3) and therefore players may have had to slow their movement down for better control of the ball.

3.5.3 Technical Outputs

This is the first study to examine the effect of varying playing number on technical outputs during a non sport-specific SSG in young athletes. The results indicate that technical outputs were reduced as player number increased. More specifically, the number of possessions, passes, catches and shots were higher during 3 vs. 3 bucketball compared to 4 vs. 4 and 6 vs. 6 (Table 3.3). This result agreed with previous studies investigating soccer SSGs that reported similar findings (Casamichana & Castellano, 2010; Dellal, Chamari, et al., 2011; Katis & Kellis, 2009; Owen et al., 2011). However, the specific skills involved in a catch and pass game compared with soccer are considerably different, and therefore comparisons are difficult to make. In the present study, more time was spent by players “off the ball” during the 4 vs. 4 and 6 vs. 6 games. Players would therefore be required to work harder while not in possession to lose their marker and create passing opportunities for their team mates. This can be achieved effectively by alternating between very slow movements and high speed runs over sustained distances. Indeed, this tactic may have been employed by the players in the present study and contributed to the differences in time-motion characteristics we observed.

In summary, to our knowledge this is the first study to report the physiological, time-motion and technical responses of a non sport-specific SSG in young team sport players. This study demonstrated that a 'general' catch and pass SSG can elicit sufficient training stimulus to potentially improve aerobic fitness in young athletes. There was a tendency for the smaller team game format (3 vs. 3) to elicit greater physiological responses than larger teams. Finally, games with fewer players induced more physical and technical outputs than larger teams.

3.6 Practical applications

It is important for coaches and sport scientists working with team sports to understand how to manipulate SSG variables to achieve a desired physical or technical adaptation. Based on the results presented in this study, we recommend that coaches of young (<14 years) team sport players consider the addition of an non sport-specific 3 vs. 3 SSG to their training regime for the purpose of increasing aerobic fitness. Given that a catch and pass game incorporates fundamental skills, it may be considered as a useful training tool by coaches in a wide range of team sports. For players involved in sports during which possession is controlled with the hands, it will not only provide an opportunity to improve aerobic fitness but develop technical game skills (including passing, catching, and shooting) at the same time. Furthermore, it may also provide benefits to young players involved in sports where game intensity is reliant on a reasonably high level of skill to maintain control of the ball (e.g.

soccer, hockey). For these sports, a non sport-specific catch and pass SSG may be adopted during specific training phases for the purpose of increasing aerobic fitness.

Chapter 4: Small-sided games for young athletes: Is game specificity influential?

4.1 Introduction

Intermittent team sports such as soccer require athletes to have well developed aerobic fitness in order to recover quickly between high-intensity running efforts and sustain these efforts for the duration of a match (Bishop & Spencer, 2004). However, while a well developed aerobic system is important, team sport athletes also require high levels of technical skill and decision making ability. For young athletes (<14 years), the relative importance of physiological versus skill development is most likely different to that of their older counterparts. Accordingly, team sport coaches should consider the most effective methods for aerobic, technical and tactical adaptation specific to the requirements and capabilities of the athletes they are working with.

Training protocols to enhance aerobic fitness in young athletes are limited in the literature. Those that exist differ widely in their exercise type, intensity, duration and work: rest ratio, making it difficult to draw conclusions on their effectiveness and make practical applications (Baquet et al., 2002; Baquet et al., 2010; Kobayashi et al., 1978; Mahon & Vaccaro, 1989a). Indeed, maturation level, prior experience and training environment all play a role in determining the success of a particular training regime in both attaining sufficient stimulus and encouraging enjoyment and long term adherence (Gabbett et al., 2008; Krivolapchuk, 2011).

Young athletes often find it difficult to adhere to traditional aerobic fitness training, such as continuous moderate-intensity training or repeated high-intensity efforts, because of a lack of enjoyment and experience with this type of exercise (Wall & Côt, 2007). A compromised willingness to work at the required intensity and duration during such types of training will likely limit potential training adaptations. To address this, alternative training strategies have been developed (Hoff et al., 2002) to encourage young athletes to train at the desired workload. In particular, the use of small-sided games (SSGs) to develop sport specific aerobic fitness has become increasingly prevalent in team sport environments (Dellal, Jannault, Lopez-Segovia, & Pialoux, 2011; Hill-Haas et al., 2010) especially since technical and tactical components can be developed concomitantly. Indeed, studies to date have investigated the acute physiological responses and time-motion responses related to SSG regimes in both adults (>18 years) (Rampinini et al., 2007) and youth (14 – 18 years) athletes (Foster et al., 2010; Hill-Haas et al., 2010; Hill-Haas, Dawson, et al., 2009). Furthermore, SSG training in youths (Buchheit, Laursen, et al., 2009; Hill-Haas, Coutts, et al., 2009) and adults (Impellizzeri et al., 2006) have been shown to be equally effective at improving aerobic fitness compared to intensity matched, interval running training.-.

To date, most research has focused on quantifying the physical and technical responses to soccer based SSGs in highly skilled players (Hill-Haas, Dawson, et al., 2009; Owen et al., 2011; Rampinini et al., 2007), who are able to accurately control and move the ball with the feet, as well as pass, to retain possession. Despite the positive outcomes in a range of these studies, little consideration has been made of the use of SSGs in younger players who are likely to have less technical skill than their older counterparts (Vänttinen, Blomqvist, & Häkkinen, 2010). This is an important consideration since to maintain a high intensity necessary for optimal aerobic adaptation during SSGs, adequate levels of technical skill are required (Hill-Haas et al., 2011).

Non sport-specific SSGs that require fundamental technical skills to control possession (e.g. catch and pass) may allow players across a wide range of team sports to maintain a high level of intensity during play, and therefore be well suited to developing aerobic fitness in young athletes. Further research is needed to better understand the interaction between physiological variables and technical components during various types of SSGs. Therefore, the aim of this study was to quantify and compare the physiological, physical and technical demands associated with a sport specific and non-sport specific SSG in young athletes.

4.2 Methods

4.2.1 Experimental approach

A cross-over, descriptive design was used in the study which lasted 4 weeks. All players completed a multi-staged incremental treadmill run to determine peak oxygen uptake ($\dot{V}O_{2peak}$) and maximum heart rate (HR_{peak}) and thereafter participated in 3 vs. 3 and 6 vs. 6 player formats of a sport-specific and non sport-specific SSG. The pitch size was altered to keep the relative pitch area per player consistent for each game format (Table 4.1). A 1-week training period was used to familiarise participants with testing procedures and SSG formats. At the end of this time players were given scores using a 5-point scale (1 = poor, 5 = excellent) for technical skill and game intelligence by an experienced coach, and for fitness based on their $\dot{V}O_{2peak}$. The scores were tallied to give an overall ranking and used to allocate players into balanced teams. Players were selected on the same team against the same opponents as often as possible. The SSGs were performed twice at least 48 hours apart, with consistent coach encouragement and in random order.

4.2.2 Participants

Ten young male soccer players (mean ± SD: age, 13.0 ± 0.3 years, height, 157.9 ± 5.2 cm, body mass, 47.1 ± 5.5 kg, and $\dot{V}O_{2peak}$, 54.4 ± 4.9 $ml \cdot kg^{-1} \cdot min^{-1}$) participated in the study. Their mean age of peak height velocity (PHV) was -0.8 ± 0.4 years using a non-invasive and practical method to estimate their maturity levels based upon anthropometric variables (Mirwald et al., 2002). All participants were recreationally trained and involved in at least two training sessions per week, plus a game in a regional club competition. The average length of participation in soccer was 5 years. Participants and their parents (or guardians) were informed of the procedures and were required to give written informed consent and assent respectively. This study was approved for experimentation involving human subjects by the Auckland University of Technology Ethics Committee.

4.2.3 Procedures

Peak oxygen uptake ($\dot{V}O_{2peak}$) was determined during an incremental treadmill running test on a motorised treadmill (PowerJog, Birmingham, UK) (Armstrong et al., 1999). Briefly, after a 3 min warm-up at 6 $km \cdot hr^{-1}$ and 1% gradient, the treadmill speed was set at 8 $km \cdot hr^{-1}$ for the initial 3 min stage and increased to 10 $km \cdot hr^{-1}$ for the next stage. Thereafter, treadmill speed was held constant at 10 $km \cdot hr^{-1}$ and the gradient increased by 2.5% every 3 min until the participant reached volitional exhaustion. Participants were verbally encouraged to provide a maximal effort during the final stages of the test. Throughout the test, pulmonary gas exchange was measured using a metabolic cart (Parvo TrueOne, UT, USA) which was calibrated for gas and volume prior to each test using alpha grade gases and known volumes. The $\dot{V}O_{2\ peak}$ was defined as the highest 30 s average $\dot{V}O_2$ attained during the test. Heart rate was monitored using short-range telemetry (Polar s610, Kemplele, Finland) and the peak (HR_{peak}) determined as the highest HR attained during the test.

Bucketball is a two-sided non-sport specific game during which the main objective is to score a goal in the opposing team’s bucket (Harrison, Gill, Kinugasa, & Kilding, 2013) . Running with the ball is permitted and it may be passed from the hands, player to player, in any direction. Possession is maintained until the ball is dropped, or goes out of play. To score, the player must be outside of the bucket circle. Play resumes by the team that conceded a goal from the top of their bucket circle. Passes may be intercepted and possession may be stolen from the player with the ball by the opposition dislodging it from their hands however the attacking player cannot be held in any way by the defender. In both bucketball and soccer, all players had to be inside the opposition's half when the shot was made for a goal to be validated and additional balls were placed along the side-lines to ensure play resumed quickly after a ball went out of play. Bucketball and soccer were implemented across 2 SSG formats, comprising 3 vs. 3 and 6 vs. 6 players (Table 4.1). Games lasted 16 min and players performed each SSG twice (8 games in total) in random order. All games were played outdoors on a dry grass surface in temperate conditions (14-18°C, 50-65% relative humidity, rH).

Table 4.1 – Summary of the formats for the specific and non-specific small sided games

	Game format			
	Bucketball		Soccer	
Rules	• No goalkeepers • Played with a size 4 handball • Unlimited number of steps with ball • Ball can be 'stolen' from the hands of player in possession • Possession lost when ball is dropped, goes out of play or a bucket is scored		• No goalkeepers • Played with a size 5 football • Unlimited number of steps with ball • Ball-carrier can be 'tackled' by opponent to seize the ball • Possession lost when ball goes out of play or a goal is scored	
Variables				
Player number	3 vs. 3	6 vs. 6	3 vs. 3	6 vs. 6
Game duration (min)	16 continuous		16 continuous	
Playing area size (m)	25 x 35	35 x 49	25 x 35	35 x 49
Bucket size (h x d) (cm)	47 x 41			
Bucket circle (r) (cm)	200			
Goals size (h x w) (cm)			120 x 180	

Each player wore a portable global positioning system (GPS) unit (VX Sport 220, Visuallex Sport International, Wellington, New Zealand) to determine time-motion characteristics during all SSGs. The GPS system sampled at 4 Hz and provided speed and distance data. Speed data was classified into 4 zones: standing or walking (0-6.9 $km \cdot hr^{-1}$), jogging (7-12.9 $km \cdot hr^{-1}$), running (13-17.9 $km \cdot hr^{-1}$), and sprinting (>18 $km \cdot hr^{-1}$) (Hill-Haas, Dawson, et al., 2009). GPS technology has been shown to offer a valid and reliable way of measuring distance and movement speed by players involved in team sports (%TEM = >10%) (Johnston et al., 2012) All SSGs were recorded using a high-speed digital video camera positioned overhead (Canon G11, Canon Inc, Tokyo, Japan) and post-game notation analysis undertaken to determine each player's skill executions. The following executions were quantified by an experienced technical analyst: number of possessions, number of passes and shots, successful and unsuccessful passes and shots, and goals scored. A successful pass was defined as one that was either caught or capable of being caught by a player on the same team as the player who made the pass.

The HR of each player was recorded during each SSG at 5 s intervals using radiotelemetry (Polar s610, Kemplele, Finland). The HR_{mean} and HR_{peak} of all SSGs were determined. Relative exercise intensity of each SSG was expressed as percent HR_{peak} (as determined from the incremental test) and classified into 4 intensity zones: zone 1 (<75% HR_{peak}), zone 2 (75-84% HR_{peak}), zone 3 (85-89% HR_{peak}), and zone 4 (>90% HR_{peak}) (Gore, 2000). Ratings of perceived exertion (RPE) were determined using the 6-20 linear Borg scale (Borg, 1982) at the completion of each SSG. Players were asked to rate their perceived exertion on the entire game rather than at the time of rating. The typical error of RPE for SSGs has been shown to be 1-2 units (Hill-Haas et al., 2008).

4.3 Statistical analysis

Data were log-transformed to reduce bias due to nonuniformity of error and analysed using a customised spreadsheet (Hopkins, 2006b). To make assumptions about true (population) values of the effect of different small sided games formats on physiological variables, time-motion characteristics and skill executions, the uncertainty of the effect was expressed as 90% confidence limits and as likelihoods that the true value of the effect represents substantial change. The chances that the true (population) differences are substantial were assessed using 0.2 standardised units (change in mean divided by the between subject SD) and expressed as both percentages and qualitatively, using practical inferences (Hopkins, 2006b). Magnitudes of change were classified as < 0.5% (almost certainly not), < 5% (very unlikely), < 25% (unlikely), 25-75% (possibly, possibly not), ≥ 75% (likely), ≥ 95% (very likely), ≥ 99.5% (almost certainly).

4.4 Results

4.4.1 Physical demands

Time-motion characteristics are presented in Table 4.2. Players travelled more total distance (4.9 ± 4.1%) and distance jogging at 7-12.9 $km \cdot hr^{-1}$ (14.5± 12.5%) during 3 vs. 3 bucketball than 3 vs. 3 soccer (Table 4.2). Similarly for 6 vs. 6 games, players travelled more total distance (8.3 ± 6.6%) and distance jogging at 7-12.9 $km \cdot hr^{-1}$ (14.9 ± 16.1%) and running at 13-17.9 $km \cdot hr^{-1}$ (32.3 ± 21.2%) during bucketball than soccer (Table 4.2).

4.4.2 Technical demands

Players had more total possessions, and made more passes and shots during 3 vs. 3 bucketball compared to soccer (Table 4.2). However, only total shots showed a substantial difference between games for the 6 vs. 6 playing format. The percent of successful passes and shots for bucketball substantially exceeded soccer in both game formats (Table 4.2).

4.4.3 Physiological demands

Physiological and perceptual characteristics are presented in Table 3. For 3 vs. 3 games, there was a likely substantial difference for percent HR_{peak} (2.3 ± 2.1%), and time spent in the highest HR zone (47.1 ± 121.9%) for bucketball compared to soccer (Table 4.3). For 6 vs. 6 games, there was also a likely substantial difference for percent HR_{peak} (3.1 ± 4.5%) and time above 90% HR_{peak} (55.2 ± 239.6%) during bucketball compared to soccer (Table 3). Only a small difference was observed between 3 vs. 3 games for RPE (3.4 ± 6.5%), whereas RPE were 7.0 ± 7.2% higher for bucketball than for soccer in the 6 vs. 6 format (Table 4.3).

Table 4.2 – Comparison of time-motion characteristics and technical skill executions for 3 vs. 3 and 6 vs. 6 game formats

	Game Format 3 vs. 3						Game Format 6 vs. 6					
					Chances that the true differences are substantial*						Chances that the true differences are substantial*	
	BB	SC	Difference; ±90% CL	Effect size; ±90% CL	%	Qualitative	BB	SC	Difference; ±90% CL	Effect size; ±90% CL	%	Qualitative
TD (m)	1422 ± 95	1356 ± 139	-66.5; ± 50.9	-0.43 (small); ±0.33	88	Likely	1449 ± 103	1334 ± 156	-114.6; ±85.6	-0.73 (moderate); ±0.55	95	Likely
TD at 0 – 6.9 km·hr^{-1} (m)	683 ± 68	702 ± 36	18.6; ± 33.5	0.29 (unclear); ±0.53	62	Possibly	653 ± 44	683 ± 68	30.2; ±27.4	0.47 (small); ±0.43	86	Likely
TD at 7 – 12.9 km·hr^{-1} (m)	587 ± 78	507 ± 103	-79.9; ±58.1	-0.75 (large); ±0.55	95	Very likely	538 ± 67	468 ± 116	-70.4; ±67.8	-0.66 (moderate); ±0.64	89	Likely
TD at 13 – 17.9 km·hr^{-1} (m)	152 ± 58	130 ± 45	-21.8; ±14.2	-0.26 (trivial); ±0.17	74	Possibly	219 ± 75	156 ± 80	-63.1; ±32.4	-0.77 (moderate); ±0.39	99	Very likely
TD at > 18 km·hr^{-1} (m)	13 ± 15	18 ± 17	5.4; ±6.7	0.17 (trivial); ±0.21	40	Possibly	39 ± 48	25 ± 24	-14.3; ±26.7	-0.45 (unclear); ±0.85	70	Possibly
Total possessions	26.6 ± 7.7	22.9 ± 6.4	-3.7; ±4.5	-0.56 (small); ±0.68	82	Likely	15.8 ± 4.6	17.7 ± 4.5	1.9; ±2.9	0.28 (unclear); ±0.43	63	Possibly
Total passes	18.2 ± 7.0	15.8 ± 5.3	-2.5; ±4.5	-0.41 (unclear); ±0.73	69	Possibly	12.4 ± 4.9	14.6 ± 5.6	2.2; ±3.2	0.35 (unclear); ±0.52	70	Possibly
Successful passes (%)	90.7 ± 7.1	70.0 ± 12.3	-21.0; ±8.2	1.0 (moderate); ±0.57	100	Almost certainly	84.7 ± 12.9	59.8 ± 17.4	-23.5; ±9.3	-1.64 (large); ±0.65	100	Almost certainly
Total shots	7.5 ± 2.8	3.3 ± 1.9	-4.2; ±1.8	-1.8 (large); ±0.78	100	Most likely	3.1 ± 1.9	1.3 ± 1.1	-1.9; ±1.4	-0.79 (moderate); ±0.59	95	Very likely
Successful shots (%)	54.9 ± 22.0	31.5 ± 18.3	-23.8; ±19.0	-0.93 (moderate); ±0.70	95	Very Likely	37.7 ± 32.8	15.4 ± 21.9	-22.3; ±23.6	-0.87 (moderate); ±0.92	89	Likely

*Substantial is a change of >0.20 standardised units for all measures. BB = bucketball; SC = soccer; RPE = rating or perceived exertion; AU = arbitrary units.

Table 4.3 - Comparison of physiological and perceptual responses for 3 vs. 3 and 6 vs. 6 game formats

	Game Format 3 vs. 3						Game Format 6 vs. 6					
					Chances that the true differences are substantial*						Chances that the true differences are substantial*	
	BB	SC	Difference; ±90% CL	Effect size; ±90% CL	%	Qualitative	BB	SC	Difference; ±90% CL	Effect size; ±90% CL	%	Qualitative
%HR_{peak}	89.5 ± 3.1	87.4 ± 2.8	-2.1; ±1.8	-0.53 (small); ±0.46	89	Likely	86.4 ± 3.1	83.7 ± 4.2	-2.7; ±3.6	-0.68 (moderate); ±0.94	81	Likely
Time spent below 75% HR_{peak} (s)	11 ± 17	20 ± 14	-8.6; ±13.7	-0.10 (trivial); ±0.16	14	Unlikely	43 ± 58	114 ± 152	70.7 ±106.6	0.82 (moderate); ±1.23	81	Likely
Time spent at 75 - 84% HR_{peak} (s)	143 ± 164	270 ± 140	126.8; ±124.4	0.65 (moderate); ±0.64	89	Likely	254 ± 208	374 ± 132	119.4; ±145.3	0.61 (moderate); ±0.74	83	Likely
Time spent at 85 - 89% HR_{peak} (s)	236 ± 143	309 ± 144	72.3; ±104.2	0.58 (small); ±0.83	79	Likely	264 ± 89	236 ± 109	-28.3; ±75.7	-0.23 (unclear); ±0.61	53	Possibly
Time spent above 90% HR_{peak} (s)	570 ± 288	361 ± 288	-208.2; ±228.6	-0.74 (moderate); ±0.81	87	Likely	393 ± 225	237 ± 182	-156.4; ±185.7	-0.56 (small); ±0.66	83	Likely
RPE (au)	15.1 ± 1.0	14.6 ± 1.1	-0.5; ± 0.9	-0.39 (unclear); ±0.71	68	Possibly	14.9 ± 1.0	13.9 ± 1.8	-1.0; ±0.9	-0.73 (moderate); ±0.72	90	Likely

*Substantial is a change of >0.20 standardised units for all measures. BB = bucketball; SC = soccer; RPE = rating or perceived exertion; AU = arbitrary units.

4.5 Discussion

The purpose of this study was to the compare the physiological responses, physical and technical demands during sport-specific and non sport-specific SSGs in young athletes. The study demonstrated greater distance travelled, technical executions completed and higher physiological workloads during the non sport-specific SSG.

To our knowledge, this study is the first to compare the physical outputs between SSGs of different sports. Differences between bucketball and soccer were assessed using 2 playing formats (3 vs. 3 and 6 vs. 6) with field size relative to playing number (Hill-Haas, Dawson, et al., 2009). Players covered more total distance during bucketball compared to soccer for both 3 vs. 3 and 6 vs. 6 SGGs. In addition, players travelled more distance at 7-12.9 $km \cdot hr^{-1}$ during 3 vs. 3 and 6 vs. 6 bucketball and at 13-17.9 $km \cdot hr^{-1}$ during 6 vs. 6 bucketball than during the equivalent soccer formats (Table 4.2). The capacity of young athletes to perform high-intensity actions during SSGs may be dependent on their ability to execute various technical actions the game requires. Indeed, in the present study players completed more successful passes during bucketball games than during soccer (Table 4.2) allowing play to occur at higher speeds overall. Furthermore, the technical and tactical requirements to evade an opposing player in bucketball are different to those in soccer. The rules of bucketball allow players to run ‘through’ the opposition while in possession with minimal risk of losing the ball. To regain possession defending players must restrict the attacker’s movement and dislodge the ball from their hands or wait for a passing mistake or intercept to be made. In contrast, during soccer SSGs, defenders can regain possession and disrupt play by making regulation tackles (Hill-Haas, Dawson, et al., 2009). For this reason, the young athletes involved in this study may have found it more difficult to move at higher speeds during soccer compared to bucketball due to a reduced technical ability to control the ball for long periods of time. Although there are no similar studies that have compared the demands of two different SSGs, previous research has compared SSG outputs from amateur and professional soccer players who differ in skill level (Dellal, Hill-Haas, Lago-Penas, & Chamari, 2011). The study reported that professional soccer players performed more high-intensity running and completed a higher percent of successful passes compared to amateur players during 3 vs. 3 games when players were restricted to either one touch or two touch play. The researchers proposed that the differences observed in time-motion characteristics were a result of reduced technical abilities of the amateur players. Collectively these results demonstrate that different game structure and technical skills required for bucketball are likely to explain the differences seen in time-motion characteristics between the two SSGs played.

In terms of physiological responses, a likely difference in mean $\%HR_{peak}$ was demonstrated between bucketball and soccer for 3 vs. 3 (89.5% and 86.4%, respectively) and 6 vs. 6 games (87.4% and 83.7%, respectively) (Table 4.3). These findings agree with previous SSG studies investigating the effect of altering player number on game intensity which report HR values ranging from 87.6 to 90.6 percent of HR_{peak} (Fanchini et al., 2011; Katis & Kellis, 2009; Little & Williams, 2006) and 82.8 to 87.5 percent HR_{peak} for 3 vs. 3 and 6 vs. 6, respectively (Hill-Haas, Dawson, et al., 2009; Katis & Kellis, 2009; Little & Williams, 2006). In addition, more time was spent above 90% HR_{peak} during bucketball than soccer for both 3 vs. 3 and 6 vs. 6 game formats. The nature of the technical demands in bucketball most likely account for the different findings in intensity reported. Soccer is a highly skilled game requiring players to accurately control and move the ball with the feet, as well as pass, to retain possession. In contrast, bucketball requires players to catch and pass the ball with the hands while moving in any direction. For this reason, bucketball is arguably a less technical game than soccer therefore allowing players to maintain a higher intensity during play. However, despite a substantial difference in time spent above 90% HR_{peak} between specific and non-specific SSGs, higher variability existed during 6 vs. 6 compared to 3 vs. 3 SSGs (Table 4.2). Therefore, independent of game specificity, game ‘flow’ may be harder to achieve for young players when higher numbers are involved.

The ability of players to maintain continuous play is likely a key determinant of exercise intensity during SSGs. This challenge has been recognised by several researchers, especially in studies involving soccer, where conscious efforts have been made to ensure replacement balls are positioned around the playing area for when one goes out of play (Katis & Kellis, 2009). In the present study, for 3 vs. 3 games, the total number of possessions were higher during bucketball compared to soccer (Table 4.2), indicating that players had a greater individual involvement with the ball during the game. Increased possession during play may have also led to more passes during bucketball in the present study. Passing is associated with short, high-intensity efforts (Dellal, Lago-Penas, et al., 2011) which when performed more often may contribute to a higher physiological workload. Interestingly, the percent of successful passes during both 3 vs. 3 and 6 vs. 6 bucketball games was also substantially higher than soccer (Table 4.2). Higher accuracy in movement of the ball from player to player during the bucketball games may have resulted in an increased ‘flow’ of the game, allowing for a higher intensity to be maintained. Since high intensities are important for improving aerobic fitness during training (Helgerud et al., 2007; Hoff et al., 2002), these findings indicate that less technical SSGs may be more suitable for successful aerobic fitness adaptation in young athletes.

The role of exercise intensity on aerobic fitness adaptation during SSGs is essential to consider when prescribing training. From a team coach perspective, in the absence of heart rate technology, RPE may be used as a good global indicator of exercise intensity during game-specific exercise (Hill-Haas, Dawson, et al., 2009). In the present study there was a likely substantial difference in RPE between 6 vs. 6 bucketball and soccer SSGs. However, this difference was not evident for 3 vs. 3 games (Table 4.3). This finding is of interest considering both game formats showed a likely substantial difference in percent HR_{peak} (89% and 81% for 3 vs. 3 and 6 vs. 6 games, respectively). These results indicate that the use of RPE during 3 vs. 3 SSGs with young athletes may not always be an accurate indicator of physiological load, possibly due to insufficient experience to distinguish between relatively small yet substantial differences at high exercise intensities.

While it would appear that our data supports the use of a non sport-specific SSG to develop physical attributes in young athletes, the acquisition and application of skill is an important part of a young athlete's development and facilitating improvement in this area is a critical part of the coaches' role. Given that in some sports access to young athletes is often limited (i.e. 1-2 times per week), training sessions may be best directed at developing sport-specific skill rather than physical qualities. Accordingly, the use of sport-specific SSGs would seem appropriate. However, evidence supporting the use of non sport-specific games is not only restricted to improvements in physical capabilities. Recent research investigating the notion of transferability in games has demonstrated that non-specific tactical tasks exist across many invasion games (Memmert & Harvey, 2010). Consequently, coaches may be able to take advantage of the physiological benefits that non sport-specific SSGs provide, while at the same time develop tactical capabilities in their players specific to the sport they are coaching in. In addition, studies investigating skill learning indicate that the exposure of athletes in their formative years to increased structured and deliberate invasion game play improves the acquisition of perceptual and decision making skills, therefore suggesting that some transfer across sports is possible (Berry et al., 2008). These findings provide some evidence to support the use of a non sport-specific invasion SSG with young athletes. This study specifically investigated the non sport-specific game bucketball. It is possible that similar results may be observed in young athletes using various non sport-specific SSGs in which the technical aspects allow for a high game flow and few breaks in play. It may be considered that the most effective SSG for young athletes is the one that is physically demanding but also allows players to maximize and refine technical and tactical skills and decision-making abilities. Further research investigating the effects of a variety of non-sport specific SSGs on aerobic fitness adaptation and skill acquisition would seem warranted.

4.6 Conclusion

That young soccer players cover more distance at higher overall speeds and physiological workloads during a bucketball SSG compared to soccer suggests that non sport-specific SSGs could be considered a useful training tool by coaches of young athletes in a wide range of team sports. Less technical SSGs during which the ‘flow’ of play is maintained appear to allow for higher intensities in young players and therefore are better suited for the development of aerobic fitness. On the basis of our findings, the prescription of a 3 vs. 3 bucketball SSG to increase aerobic fitness would seem warranted.

Chapter 5: Small-sided games for young team sport players: Influence of team selection strategy and playing regime

5.1 Introduction

Small-sided games (SSGs) allow the simulation of sport specific movement patterns while also developing a number of physical capabilities (Buchheit, Laursen, et al., 2009). They are often considered an integral part of a team sport training regime and are prescribed to players to enhance their aerobic fitness. However, since SSGs can take many formats, an understanding of the physical and technical demands during a particular SSG format is important to ensure exercise prescription is customised to achieve the desired training outcomes. This is especially so in young players where the balance between developing physical and technical competencies may require specific attention.

The effect of altering a range of variables on training load during SSGs has been well documented (Hill-Haas, Dawson, et al., 2009; Rampinini et al., 2007). In general, games played with small numbers and in large playing areas have elicited higher heart rate, blood lactate and perceptual responses when compared with games with a higher number of players and small playing areas (Foster et al., 2010; Hill-Haas, Dawson, et al., 2009; Mello & Navarro, 2008; Rampinini et al., 2007). Furthermore, reducing the number of players on each team has also been reported to increase the quantity and quality of technical skill executions (Harrison et al., 2013; Katis & Kellis, 2009). These findings have important practical implications for young athletes since “touches” on the ball to develop technical skill should be considered alongside improving physical capabilities.

In practice, intermittent SSG protocols are very common because the rest periods allow coaches time to provide technical and tactical feedback to their players. However our current understanding of the best combination of interval and recovery durations (i.e. work:rest ratios) from a physical preparation perspective during SSGs is limited. Hill-Haas et al. (Hill-Haas, Rowsell, et al., 2009) compared the physiological and time-motion characteristics of intermittent (4 x 6 min bouts with 90 s recovery intervals) and continuous (24 min) soccer SSGs and observed that while intermittent SSGs elicited an increase in distance covered at speeds over 13 km·hr^{-1}, percent HR_{max} and RPE were significantly higher in the continuous SSG. Therefore, it is logical to consider that the prescription of a particular SSG format should be influenced by the training outcome required. Using the findings of Hill-Haas et al. (2009), this would suggest that interval SSGs training would improve the qualities of higher speed movement, while continuous SSGs training would be more suited to improving aerobic fitness.

To refine the prescription effectiveness of SSGs in young players further research investigating the optimal loading parameters is warranted. Furthermore, identifying the optimal game times in younger populations is important from an adherence and effort perspective. In addition, a wide variation in skill ability is common in young team sports players (Del Campo, Villora, Lopez, & Mitchell, 2011). It is possible that SSG team selection could influence the way the game is played and impact on the physical and technical executions of the players involved (Köklü , Ersöz, Alemdaroĝlu, Asci, & Özkan, 2012). To address this possibility, previous studies have allocated players into matched SSG teams with respect to their combined physical skill and game intelligence ability (Hill-Haas et al., 2010; Hill-Haas, Dawson, et al., 2009). Though logical, there is no evidence to indicate that this grouping strategy is required to achieve high levels of intensity (physical and technical) during SSGs with young athletes. With this in mind, the aim of this study was to determine the effects of manipulating game duration and team player allocation on the physical and skill outputs during a non-sport specific SSG in young athletes.

5.2 Methods

5.2.1 Experimental approach to the problem

The influence of different work:rest ratios and team selection strategy on physical and skill demands of a non sport-specific SSG in young athletes was investigated. A descriptive, within subjects, cross-over design study was conducted. All players completed a multi-staged incremental treadmill run to determine peak oxygen uptake ($\dot{V}O_{2peak}$) and peak heart rate (HR_{peak}) and thereafter, on 12 separate occasions, participated in various SSGs whilst various physical, technical and perceptual aspects were monitored.

5.2.2 Subjects

Twelve young male rugby players (mean ± SD: age, 13.2 ± 0.5 years, height, 165.6 ± 10.1 cm, body mass, 59.8 ± 16.9 kg, $\dot{V}O_{2peak}$: 60.0 ± 4.6 $ml^{-1}\cdot kg^{-1}\cdot min$) participated in the study. Their mean age of peak height velocity (PHV) was -0.1 ± 0.9 years using a non-invasive and practical method to estimate their maturity levels based upon anthropometric variables (Mirwald et al., 2002). All participants were recreationally trained and involved in at least two training sessions per week, plus a game. Participants and their parents (or guardians) were informed of the procedures and were required to give written informed consent and assent respectively. Approval from the institutional ethics committee for experimentation involving human subjects was gained prior to the commencement of the study.

Table 5.1 Team player allocation for balanced and unbalanced SSGs

Player Number	Technical skill level (1 = poor, 5 – excellent)	Aerobic fitness level (1 = poor, 5 – excellent)	Composite score	Balanced SSG team	Unbalanced SSG team
1	5	4	9	1	1
2	4	5	9	2	3
3	3	3	6	1	1
4	5	4	9	3	3
5	3	4	7	4	1
6	3	2	5	4	2
7	4	3	7	2	4
8	3	4	7	3	2
9	3	4	7	4	4
10	3	3	6	3	3
11	2	1	3	2	4
12	3	3	6	1	2

5.2.3 Procedures

5.2.3.1 Incremental treadmill running test

Peak oxygen uptake was determined during an incremental treadmill running test on a motorised treadmill (PowerJog, Birmingham, UK). The protocol of Armstrong et al. (Armstrong et al., 1999) was adopted. Briefly, after a 3 min warm-up at 6 km·hr^{-1} and 1% gradient, the treadmill speed was set at 8 km·hr^{-1} for the initial 3 min stage and increased to 10 km·hr^{-1} for the next stage. Thereafter, treadmill speed was held constant at 10 km·hr^{-1} and the gradient increased by 2.5% every 3 min until the participant reached volitional exhaustion. Participants were verbally encouraged to provide a maximal effort during the final stages of the test. Throughout the test pulmonary gas exchange was measured using a metabolic cart (Parvo TrueOne, UT, USA) which was calibrated for gas and volume prior to each test using alpha grade gases and known volumes. The $\dot{V}O_{2\ peak}$ was defined as the highest 30 s average $\dot{V}O_2$ attained during the test. Heart rate was monitored using short-range telemetry (Polar s610, Kemplele, Finland) and the peak (HR_{peak}) determined as the highest HR attained during the test.

5.2.3.2 Small-sided games – Bucketball

Bucketball is a two-sided evasion game during which the main objective is to score a goal in the opposing team's bucket (Harrison et al., 2013). Running with the ball is permitted and it may be passed from the hands, player to player, in any direction. The team with the ball maintains possession until the ball is dropped, goes out of play or a bucket is scored. To score, the player must be outside of the bucket circle (Figure 5.1). After a goal is scored, play resumes by the team that conceded the goal from the top of their bucket circle. Passes may be intercepted and possession may be stolen from the player with the ball by the opposition dislodging it from their hands however the attacking player cannot be held in any way by the defender. In this study, for a goal to be validated all players had to be positioned inside the oppositions half when the shot was made. Additional balls were placed along the side-lines of the playing area to ensure play resumed quickly after the ball went out of play. Participants competed in 3 vs. 3 SSGs on a 35 x 25 m pitch, differentiated by playing regime and team player allocation. Playing regimes involved: 1) 16 min of continuous play (BB^{16}); 2) 4 x 4 min bouts, with 90 s of passive rest separating each bout (BB^{4}) and 3) 8 x 2 min bouts, separated by 45 s of passive rest (BB^{2}). Each playing regime was implemented across 2 SSG formats, including balanced and unbalanced team selection (Table 1). A 1-week training period was used to familiarise participants with the SSG and testing procedures. Players performed each SSG twice (12 games total), and games were played in random order. The SSGs were played with consistent coach encouragement and held twice weekly, with at least 48 hours between sessions. All games were played outdoors on a dry grass surface in temperate conditions (16-20°C, 65-85% relative rH).

5.2.3.3 Team player allocation

Following the familiarisation period, players were assigned a score using a 5-point scale (1 = poor, 5 = excellent) for technical skill and game intelligence by an experienced coach, and for fitness based on their $\dot{V}O_{2peak}$. The two scores were added together to give a composite score for each player and used to allocate players into teams for SSGs (Table 5.1). Four teams of 3 players were selected for balanced teams using an even mix of composite scores. “Balanced” was defined as a difference of no more than 2 points between SSG teams when composite scores for the 3 players were totaled. Four teams of 3 players were also selected for unbalanced teams using an uneven mix of composite scores. “Unbalanced” was defined as a difference of no less than 3 points between SSG teams when composite scores for the 3 players were totaled. For balanced and unbalanced SSGs, team 1 played team 3 and team 2 played team 4 (Table 5.1). Players were selected on the same team and against the same opponents as often as possible during SSGs.

5.2.4 Physical demands

Each player wore a portable global positioning system (GPS) unit (VX Sport 220, Visuallex Sport International, Wellington, New Zealand) to determine time-motion characteristics during all SSGs. The GPS system sampled at 4 Hz and provided speed and distance data. Speed data was classified into 4 zones: walking (0-6.9 $km \cdot hr^{-1}$), jogging (7-12.9 $km \cdot hr^{-1}$), cruising (13-17.9 $km \cdot hr^{-1}$), and sprinting (>18 $km \cdot hr^{-1}$) (Hill-Haas, Rowsell, et al., 2009). GPS technology measuring at a frequency of 5Hz has been shown to offer a valid and reliable way of measuring distance and movement speed by players involved in team sports, however limitations do exist for high-speed running (Johnston et al., 2012).

The heart rate (HR) of each player was recorded during each SSG at 5 s intervals using radiotelemetry (VX Sport 220, Visuallex Sport International, Wellington, New Zealand). The mean (HR_{mean}) and HR_{peak} of all SSGs were determined. Relative exercise intensity of each SSG was expressed as percent HR_{peak} (as determined from the incremental test) and classified into 4 intensity zones: zone 1 (<75% HR_{peak}), zone 2 (75-84% HR_{peak}), zone 3 (85-89% HR_{peak}), and zone 4 (>90% HR_{peak}) (Gore, 2000).

5.2.5 Perceived exertion

Ratings of perceived exertion (RPE) were determined using the 6-20 linear Borg scale (Borg, 1982) at the completion of each SSG. Players were asked to base their perceived exertion on the entire game rather than at the time of rating. The typical error of RPE for SSGs has been shown to be 1-2 units (Hill-Haas et al., 2008).

5.2.6 Technical skill executions

All SSGs were recorded using a high-speed digital video camera (Canon G11, Canon Inc, Tokyo, Japan). Post-game notation analysis was undertaken to determine each player's skill executions during each game. The following executions were quantified by an experienced technical analyst: number of involvements, total and successful receives and total and successful passes. A successful pass was defined as one that was either caught or able to be caught by a player on the same team.

5.3 Statistical Analyses

Data were log-transformed to reduce bias due to nonuniformity of error and analysed using a customised spreadsheet (Hopkins, 2006b). To make assumptions about true (population) values of the effect of different small sided games formats on physiological variables, time-motion characteristics and skill executions, the uncertainty of the effect was expressed as 90% confidence limits and as likelihoods that the true value of the effect represents substantial change. The chances that the true (population) differences are substantial were assessed using 0.2 standardised units (change in mean divided by the between subject SD) and expressed as both percentages and qualitatively, using practical inferences (Hopkins, 2006b). Magnitudes of change were classified as < 0.5% (almost certainly not), < 5% (very unlikely), < 25% (unlikely), 25 – 75% (possibly, possibly not), ≥ 75% (likely), ≥ 95% (very likely), ≥ 99.5% (almost certainly).

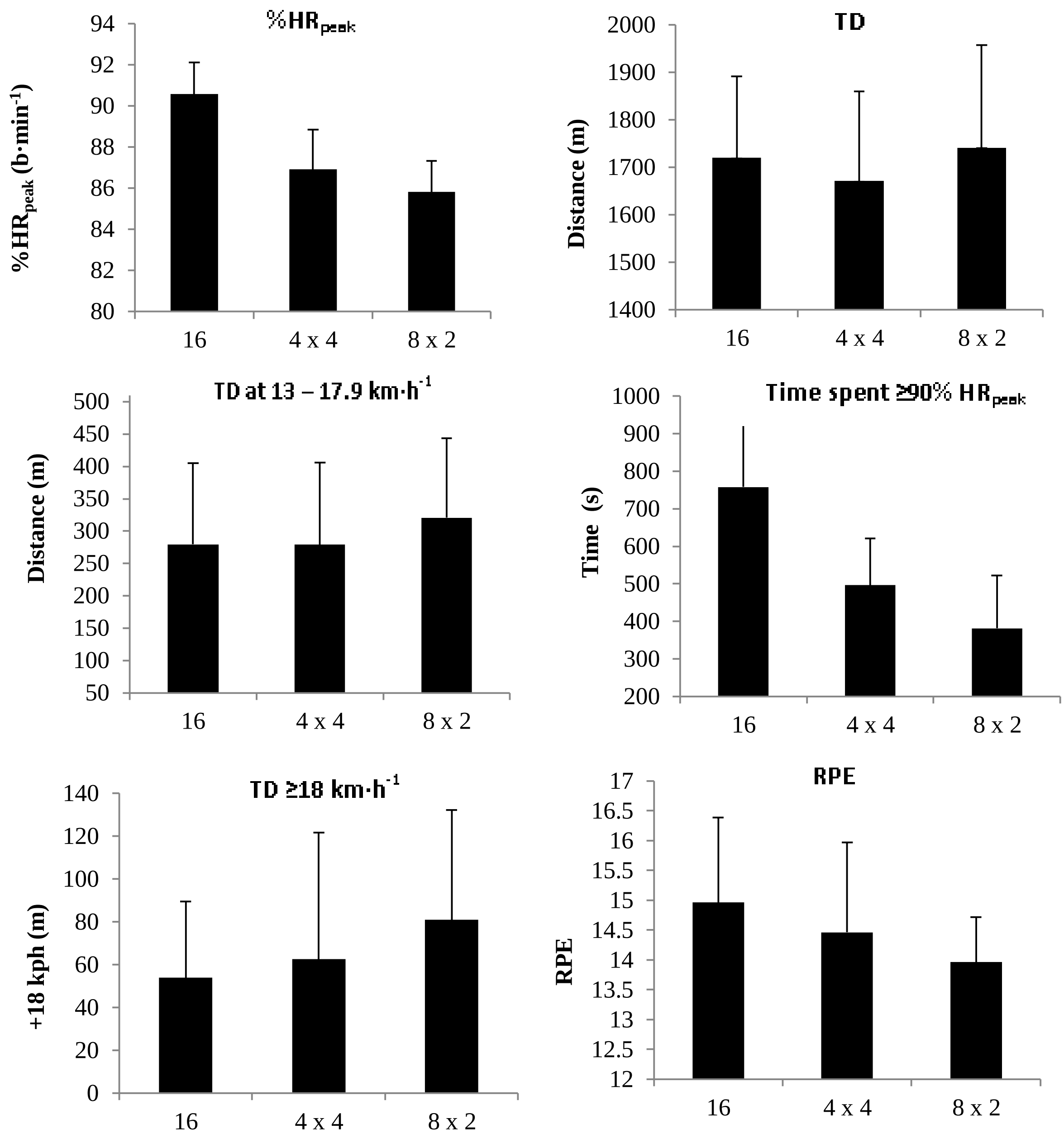


Figure 5.1. Means (±SD) for various physiological, movement and perceptual variables for continuous (16 min) and intermittent (4 x 4 min and 8 x 2 min) playing regimes.

TD = total distance, RPE = ratings of perceived exertion

Table 5.2. Differences between team allocation method (±90% confidence limits), and the magnitude of that change (effect size) for Bucketball SSGs

					Chances that the true differences are substantial*	
	Balanced	Unbalanced	Difference (%)	Effect size	%	Qualitative
%HR_{peak} (b·min^{-1})	88.2 ± 1.2	86.8 ± 1.7	1.3; ± 0.9	0.65; ± 0.46	95	Likely
Time spent ≥90% HR_{peak} (s)	546 ± 116	446 ± 158	21.9; ± 26.6	0.49; ± 0.46	86	Likely
TD (m)	1711 ± 161	1659 ± 157	3.1; ± 2.7	0.23; ± 0.20	60	Possibly, possibly not
TD at 13-17.9 km·hr^{-1} (m)	293 ± 108	267 ± 97	9.7; ± 10.8	0.09; ±0.09	3	Very unlikely
TD ≥18 km·hr^{-1} (m)	69 ± 61	42 ± 34	7.3; ± 62.6	0.57; ± 0.43	92	Likely
RPE	14.5 ± 0.8	14.2 ± 0.9	1.8; ± 2.9	0.22; ± 0.36	54	Possibly, possibly not
Total involvements	28.4 ± 4.8	27.2 ± 3.8	3.6; ± 7.6	0.23; ± 0.45	54	Possibly, possibly not
Total Receives	28.3 ± 4.6	28.0 ± 3.0	0.5; ± 7.3	0.04; ± 0.59	32	Possibly, possibly not
Effective receives (%)	97.2 ± 2.0	95.8 ± 3.0	1.5 ± 1.2	0.13 ± 0.10	11	Unlikely
Total passes	17.4 ± 3.6	17.4 ± 3.3	0.1; ± 10.0	0.1; ± 0.59	27	Possibly, possibly not
Effective passes (%)	86.8 ± 4.5	85.4 ± 5.0	1.7; ± 2.6	0.11; ± 0.16	16	Unlikely

BB = Bucketball; HR = heart rate; TD = total distance; RPE = rating of perceived exertion.

Table 5.3. Differences between playing regimes (±90% confidence limits), and the magnitude of that change (effect size) for balanced team allocation

	$BB^{16} – BB^{4}$				$BB^{16} – BB^{2}$				$BB^{4} – BB^{2}$			
			Chances that the true differences are substantial*				Chances that the true differences are substantial*				Chances that the true differences are substantial*	
	Difference (%)	Effect size	%	Qualitative	Difference	Effect size	%	Qualitative	Difference (%)	Effect size	%	Qualitative
$\%HR_{peak}$ (b·min^{-1})	4.0; ± 1.2	-1.82; ± 0.53	100	Almost certainly	5.3; ± 1.2	-2.38; ± 0.55	100	Almost certainly	1.3; ± 1.6	-0.56; ± 0.69	81	Likely
Time spent ≥90% HR_{peak} (s)	30.9; ± 33.4	-0.69; ± 0.54	94	Likely	50.7; ± 19.5	-1.32; ± .033	100	Almost certainly	28.7; ± 33.9	-0.63; ± 0.54	91	Likely
TD (m)	3.0; ± 5.2	-0.22; ± 0.36	54	Possibly, possibly not	-0.9; ± 7.2	0.07; ± 0.50	32	Possibly, possibly not	-4.0; ± 4.6	0.28; ± 0.33	68	Possibly, possibly not
TD at 13-17.9 km·hr^{-1} (m)	1.7; ± 25.1	-0.03 ± 0.38	22	Unlikely	-16.5; ± 24.4	0.26; ± 0.39	61	Possibly, possibly not	-18.6; ± 15.9	0.29; ± 0.25	74	Possibly, possibly not
TD ≥18 km·hr^{-1} (m)	12.4; ± 54.1	-0.10; ± 0.34	31	Possibly, possibly not	-25.1; ± 33.2	0.17; ± 0.22	42	Possibly, possibly not	-52.0; ± 49.0	0.33; ± 0.31	76	Likely
RPE	3.4; ± 7.2	-0.33; ± 0.66	64	Possibly, possibly not	6.4; ± 5.3	-0.63; ± 0.49	93	Likely	3.1; ± 6.5	-0.30; ± 0.60	61	Possibly, possibly not
Total involvements	-1.4; ± 15.9	0.05; ± 0.51	30	Possibly, possibly not	-4.5; ± 17.1	0.15; ± 0.55	44	Possibly, possibly not	-3.1; ± 12.5	0.10; ± 0.41	34	Possibly, possibly not
Receives	-2.8; ± 17.7	0.09; ±0.54	36	Possibly, possibly not	-4.9; ± 20.4	0.16; ± 0.61	45	Possibly, possibly not	-2.1; ± 14.8	0.07; ± 0.46	31	Possibly, possibly not
Effective receives	1.7; ± 2.3	-0.47; ± 0.64	77	Likely	1.2; ± 2.1	-0.34; ±0.59	66	Possibly, possibly not	-0.5; ±1.4	0.13; ± 0.39	37	Possibly, possibly not
Total passes	-10.0; ± 24.7	0.27; ± 0.62	58	Possibly, possibly not	-11.2; ± 21.6	0.30; ± 0.55	62	Possibly, possibly not	-1.1; ± 16.4	0.03; ± 0.43	24	Possibly, possibly not

Effective passes	-3.0; ± 8.9	0.23; ± 0.65	54	Possibly, possibly not	-1.1; ± 10.4	0.08; ± 0.78	40	Possibly, possibly not	1.9; ± 6.3	-0.15; ± 0.49	43	Possibly, possibly not

BB = Bucketball; HR = heart rate; TD = total distance; RPE = rating of perceived exertion

5.4 Results

The mean (± SD) physiological, time-motion and perceptual results for the different SSG playing regimes are presented in Figure 5.1.

5.4.1 Team allocation method

Data is presented as a composite of continuous and intermittent SSGs. Physiological, time-motion and perceptual differences for the two team allocation methods, together with the magnitude of the difference, are presented in Table 5.2. Percent HR_{peak} and time spent above 90% HR_{peak} were substantially higher for balanced compared to unbalanced team allocation. There was no substantial difference for TD at 13 – 17.9 $km{\cdot}hr^{-1}$ between team allocation methods. Total distance ≥18 $km{\cdot}hr^{-1}$ for the balanced SSGs exceeded unbalanced games. No differences in technical skill executions between team allocation methods were observed (Table 5.2).

5.4.2 Game duration

Considering game intensity for matched SSGs exceeded those of randomised games, results for the three playing regimes for this method of team allocation are presented (Table 5.3). Percent HR_{peak} was higher for BB^{16} compared to both BB^{4} and BB^{2} games (90.6 ± 1.6 $b{\cdot}min^{-1}$, 86.9 ± 1.9 $b{\cdot}min^{-1}$, and 85.8 ± 1.5 $b{\cdot}min^{-1}$, respectively). Similarly, time spent above 90% HR_{peak} for BB^{16} exceeded BB^{4} and BB^{2} games (758 ± 216 s, 497 ± 125 s and 381 ± 125 s, respectively). Ratings of perceived exertion were substantially higher for BB^{16} compared to BB^{4} but not BB^{2}. No difference in RPE existed between intermittent games. Substantial differences in time-motion characteristics were observed for TD ≥18 $km{\cdot}hr^{-1}$ between BB^{16} and BB^{2} and BB^{4} and BB^{2}. Effective receives was higher in BB^{16} compared to BB^{4} but no other differences in technical skill executions for playing regime were observed (Table 5.3).

Figure 5.2 presents means (± SD) for $\%HR_{peak}$ during the work and recovery periods for the intermittent playing regimes.

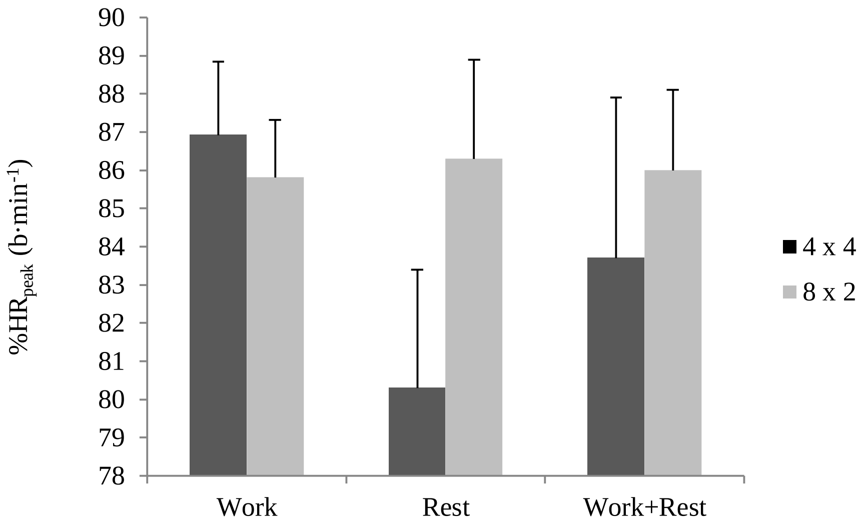


Figure 5.2. Mean (±SD) $\%HR_{peak}$ during work, rest and work+rest periods for 4 x 4 min and 8 x 2 min intermittent SSGs.

5.5 Discussion

It is intuitive to think that allocating team sport players into balanced teams, based on cognitive ability and fitness, during SSGs would create more competitive play and therefore encourage higher game intensities to be achieved. In the present study we sought to determine the consequential effects on physical and technical outputs when SSGs were played with balanced and unbalanced teams, combined with manipulating the nature (continuous vs. intermittent) of games. Our results indicate that differing effects are seen in exercise intensity, movement characteristics and perceptual response when continuous SSGs are compared to time-matched intermittent formats in young athletes. In addition, the method used to allocate SSG players into teams influences game intensity.

To our knowledge, this is the first study to investigate the effect of balanced versus unbalanced team allocation on SSG play in young athletes. Our findings indicated that 3 vs. 3 balanced SSGs elicited a substantially higher $\%HR_{peak}$ response and time spent above 90% HR_{peak} than the unbalanced equivalents. A likely explanation is that the difference in player fitness and skill levels on each team (Table 5.1) negatively influenced the competitiveness of play throughout the unbalanced SSGs, and decreased exercise intensity accordingly. Empirical observations suggest is it common for young athletes to decrease their intensity during SSGs either when they are dominating play or struggling to compete. In the present study, goals scored by each team during balanced games were more evenly distributed compared to randomised games (data not shown), indicating more competitive encounters. However, while allocating young players into balanced SSG teams had no effect on perceptual responses, its effect on some time-motion characteristics was apparent. More specifically, players travelled more distance at higher running speeds (≥ 18 $km \cdot hr^{-1}$) during balanced SSGs. Higher running speeds have been associated with 'decisive actions' (times during a match when the game outcome is typically decided) during soccer (Dupont, Akakpo, & Berthoin, 2004). It is possible that these periods occurred more frequently during balanced SSGs as a result of more competitive playing environments. Unfortunately, no other studies have reported on the effects of team allocation methods associated with SSGs, and therefore no comparisons are possible. The present study demonstrates the importance of balanced teams during SSGs in young athletes when the desired outcome is the highest exercise intensity possible.

Recent evidence has demonstrated that continuous 3 vs. 3, non-sport specific SSGs can elicit sufficient training stimulus to potentially improve aerobic fitness in young athletes (Harrison et al., 2013). However, SSG training is commonly structured as "interval" as opposed to continuous-duration play, particularly for young athletes, as the rest periods allow an opportunity for specific coach input. Therefore, understanding the effect of manipulating work:rest ratios during SSGs on specific physical and technical outputs in young athletes is worthwhile.

In the present study, continuous SSGs elicited a substantially higher $\%HR_{peak}$ and time spent above 90% HR_{peak} compared to intermittent SSGs (Figure 5.1). Similar results have been demonstrated when continuous and intermittent SSGs in adolescent (16.2 ± 0.2 years) soccer players were compared (Hill-Haas, Rowsell, et al., 2009). Hill-Haas et al. (2009) reported a significant increase in $\%HR_{max}$ for continuous games of 24 min compared to 4 x 6 min of intermittent play. The authors suggested that the addition of passive rest between intermittent work bouts allowed players time to recover and begin subsequent bouts with lower heart rates (Hill-Haas, Rowsell, et al., 2009). A similar physiological mechanism is most likely responsible for the differences in intensity observed between SSG regimes in young athletes in the present study. In addition, we also observed substantial differences in $\%HR_{peak}$ and time spent above 90% HR_{peak} during work bouts between BB^4 and BB^2 min intermittent SSGs. However, examination of the entire SSG bout (work + rest) during the intermittent regimes revealed that despite a lower $\%HR_{peak}$ during the work periods, the combined work and rest internal load during the SSGs was substantially higher for BB^2 compared to the results of BB^4 (Figure 5.2). In summary, rest duration appears to significantly influence the time spent at higher HRs during intermittent SSGs in young athletes, when both work and recovery HRs are considered.

Previous research with young athletes has shown that perception of effort is not influenced by varying the number of players involved in fixed duration SSGs, despite observed differences in $\%HR_{peak}$ (Harrison et al., 2013). This observation is in contrast to adolescents and adults (Hill-Haas, Dawson, et al., 2009; Hoff et al., 2002) suggesting that RPE may be a poor indicator of game intensity in young athletes who are unable to, due to lack of experience, differentiate between small changes in physical load. In the present study a likely substantial difference in RPE was observed between continuous and 2 x 8 min intermittent SSG regimes, which corresponded to the almost certain substantial difference reported in internal load. This may have allowed players to accurately distinguish between exercise intensity using RPE. Alternatively, the rest periods during the 8 x 2 min regime may have influenced the way players perceived the intensity of the SSGs. Specifically, young athletes may perceive exercise involving frequent “breaks in play” as easier than continuous and longer intermittent formats regardless of HR intensity during the work periods. Consequently, RPE may be an accurate indicator of game intensity in young athletes during game-specific exercise of distinctly different work:rest ratios.

The time-motion data from this study demonstrated no substantial differences in distance travelled below 18 $km \cdot h^{-1}$ between continuous and intermittent playing regimes. By contrast, previous SSG literature in adolescent soccer players demonstrated that players travelled greater distance at 13-17.9 $km \cdot h^{-1}$ during intermittent regimes (Hill-Haas, Rowsell, et al., 2009). It is possible that different pacing strategies of the different aged players involved might explain discrepancies in these findings (Micklewright et al., 2012). However, in the present study a substantial difference was reported for distance travelled ≥18 $km \cdot h^{-1}$ between the continuous and the 8 x 2 min intermittent regime, which agreed with previous work (Hill-Haas, Rowsell, et al., 2009). The ability to perform repeated, high-intensity exercise is reliant on the recovery of high-energy phosphates (PCr) and reduction of metabolites associated with fatigue including the potassium in the muscle (Norsborg, Bangsbo, & Pilegaard, 2003) and inorganic phosphates (Allen, Lamb, & Westerblad, 2008). Accordingly, more passive recovery opportunities during BB^2 may have permitted increased sprinting distance compared to BB^{16}. However, based on this premise, we would have expected to also see difference in higher speed running between the continuous and 4 x 4 min intermittent playing regime. It is possible that players perceived the stop-start nature of BB^2 to be less intense than BB^4 and therefore were more willing to increase the amount of sprinting they performed, knowing recovery was imminent.

The involvement and execution of technical aspects are an essential part of SSG training, particularly for young athletes for whom skill acquisition is very important. This study demonstrated no differences in the quantity or quality of technical outputs between matched and randomised team allocation playing formats. The only technical execution affected by a change in playing regime was an increase in the effectiveness of players to receive a pass during BB^{16} compared to BB^4. This finding is surprising in view of a lower game intensity during BB^4, which should have allowed players to concentrate more out of possession to successfully receive a pass. Earlier studies have reported that player number during SSGs substantially influences the quantity of technical executions performed by young athletes, with less players resulting in higher outputs (Harrison et al., 2013; Katis & Kellis, 2009). For this reason, the lack of differences in technical executions reported in the present study may simply have been the result of identical player numbers across all SSGs.

In summary, we have shown for the first time the effect of manipulating team selection strategy and work:rest ratios on the physical and skill outputs during a non-sport specific SSG in young athletes. The results of this study demonstrate that continuous SSGs balanced for team player allocation provide greater physiological load than unbalanced and intermittent games in young athletes. Alternatively, intermittent games balanced for team player allocation may offer an effective stimulus for training the associated demands of higher speed running together with providing an appropriate stimulus for extensive aerobic fitness adaptation. Lastly, it appears that balanced and unbalanced team selection, and continuous and intermittent SSGs, can be interchanged without affecting the quantity and quality of technical executions performed during a non sport-specific SSGs by young athletes.

5.6 Practical applications

Given the findings presented in this study, the coach or sport scientist is better informed to choose an appropriate SSG regime to target specific training outcomes (physical and/or technical). For the purpose on increasing aerobic fitness, we recommend the use of a non sport-specific, 3 vs. 3 continuous SSG for which balanced teams have been allocated. On the other hand, an intermittent SSG regime with multiple brief work intervals (i.e., 8 x 2 min separated by 45 s of passive recovery) is recommended to improve the characteristics of higher speed running. In addition, intermittent SSGs provide the opportunity for direct coach input during the passive recovery periods that may lead to better skill acquisition in young athletes.

Chapter 6: Effect of rule changes and inter-game conditioning exercise on small-sided game demands in young team sport athletes

6.1 Introduction

Small-sided games (SSGs) are an effective strategy to concurrently improve the physical and technical abilities of team sport athletes (Owen et al., 2011). Previous research has demonstrated that SSGs characteristics can be easily manipulated to increase the intensity of play to the same level of that observed with short-duration, intermittent running (Dellal et al., 2008). Accordingly, SSGs training has become increasingly promoted as the preferred training modality for team sport athletes over more traditional running-based training protocols (Buchheit, Laursen, et al., 2009).

Despite numerous SSGs studies investigating adult (Hoff et al., 2002; Owen et al., 2011; Rampinini et al., 2007) and adolescent (Gabbett et al., 2010; Hill-Haas, Dawson, et al., 2009) populations, there is currently little research to quantify the effects of manipulation of game variables during SSGs in young athletes (<14 years) (Harrison et al., 2013; Katis & Kellis, 2009). This is an important consideration since the training environment for young athletes is often different to that of older, more experienced athletes and requires longer term strategies for optimal results (Geithner et al., 2004).

In general, studies investigating SSGs in young athletes have demonstrated that formats with fewer players elicit higher heart rates (HR), perceptual responses and technical outputs, while more players increases the distance travelled at higher running speeds (Hill-Haas, Dawson, et al., 2009; Rampinini et al., 2007). While player number, field size and work-to-rest ratios have all been manipulated by researches to quantify differences in training stress, more recently studies have examined how rule changes to game play effect the physiological and movement characteristics and technical executions of the players involved (Gabbett et al., 2010; Hill-Haas et al., 2010; Little & Williams, 2006; Mello & Navarro, 2008; Sampaio et al., 2007). This is an important area for examination as it is common practice for coaches to stipulate playing rules during SSGs to achieve specific training outcomes. Systematically identifying the influence of different rules on the technical demands of SSGs would allow coaches to better plan and implement skill based training programmes (Klusemann, Pyne, Foster, & Drinkwater, 2012) .

Previous research that has reported the effects of technical rules changes on physical and movement outputs are limited to adolescent (Gabbett et al., 2010; Hill-Haas et al., 2010) and adult populations (Little & Williams, 2006; Mello & Navarro, 2008; Sampaio et al., 2007). At present the effects of rules changes on SSG demands in young athletes are not well understood. Training regimes for young team sport athletes should consider the relative importance of physical compared to technical and tactical outputs together with the role enjoyment plays in exercise adherence and motivation to train. With this in mind, research elucidating the unique effects manipulation of game rules has on this population of athletes is warranted.

The inclusion of more traditional conditioning exercises during SSG training, such as high-speed shuttle running, is also commonly used by coaches in practice to superimpose additional physical work on their players. High-intensity, intermittent running during which the intensity of the work period is at or near peak oxygen uptake ($\dot{V}O_{2peak}$) has the potential to improve aerobic fitness in team sport athletes (Helgerud et al., 2007). Such training protocols can be individually prescribed to control the workload across players differing in aerobic profiles (Buchheit, 2008), and therefore may be useful in combination with SSGs to influence physiological and movement demands in young athletes. Investigating this supplemental approach, Hill-Haas et al. (2010) reported an increase in total distance and high-intensity running, but not HR_{max}, in adolescent soccer players when additional sprints and sideline runners were included in SSG play. The activity of young players during SSGs is dependent on the level of technical skill, game intelligence, and / or motivation each player exhibits (Del Campo et al., 2011). It is possible that large differences in these capabilities among young, inexperienced team sport players may result in quite different physiological and movement outputs compared to more experienced, older players (Dellal et al., 2008).

Clearly, further research is required to elucidate the different ways to best manipulate SSGs to achieve specific physiological and technical outcomes. Therefore the aim of this study was to determine the effect of rule changes, and the inclusion of inter-game high-intensity running bouts, on the physiological and perceptual responses, time-motion characteristics and technical skill executions during a non sport-specific SSG in young athletes.

6.2 Methods

6.2.1 Experimental approach

The influence of games rules and additional conditioning exercises during a non-sport specific SSG in young athletes was investigated throughout a 6-week, cross-over descriptive study. During the first two weeks players performed a multi-staged incremental treadmill run to determine $\dot{V}O_{2peak}$ and maximum heart rate (HR_{peak}) and the 30-15 intermittent fitness test to determine the final running velocity (V_{IFT}). Thereafter, participants competed in various formats of a three vs. three non sport-specific SSG, differentiated by two different rule changes and the inclusion of individualised, high-intensity running bouts (Table 6.1). The SSG formats were performed twice in random order and at least 48 hours apart.

6.2.2 Participants

Ten young male team sport players (mean ± SD: age, 13.7 ± 0.5 years, height, 170.0 ± 10.4 cm, body mass, 62.4 ± 16.7 kg, and $\dot{V}O_{2peak}$, 54.5 ± 7.3 $ml \cdot kg^{-1} \cdot min^{-1}$) participated in the study. Their mean age of peak height velocity (PHV) was 0.35 ± 0.9 years using a non-invasive and practical method to estimate their maturity levels based upon anthropometric variables (Mirwald et al., 2002). All participants were recreationally trained and involved in at least two training sessions per week, plus a game in a regional school competition. Participants and their parents (or guardians) were informed of the procedures and were required to give written informed consent and assent respectively. This study was approved for experimentation involving human subjects by the Auckland University of Technology Ethics Committee.

Table 6.1 – Summary of small-sided games variables and formats.

	Game variables			
	Player number	Game duration	Playing area size	Area per player
	3 vs. 3	16 min	25 x 35 m	146 m^2
Game format				
BB	No change to bucketball (BB) rules			
BB^{3S}	3 seconds (3S): players may only be in possession of the ball for 3 s			
BB^{MM}	Man-on-man (MM): players may only mark and defend their partnered player			
BB^{HR}	Conditioning blocks at high intensity (HR): second and fourth quarter of game replaced with high-intensity running - 8 x 15 s @ 100% $V_{IFT,}$ separated by 15 s of passive rest			

Note: $V_{IFT,}$ final velocity during the 30-15 intermittent fitness test.

6.2.3 Procedures

6.2.3.1 Incremental treadmill running test

Peak oxygen uptake ($\dot{V}O_{2peak}$) was determined during an incremental treadmill running test on a motorised treadmill (PowerJog, Birmingham, UK) (Armstrong et al., 1999). Briefly, after a 3 min warm-up at 6 km·hr^{-1} and 1% gradient, the treadmill speed was set at 8 km·hr^{-1} for the initial 3-min stage and increased to 10 km·hr^{-1} for the next stage. Thereafter, treadmill speed was held constant at 10 km·hr^{-1} and the gradient increased by 2.5% every 3 min until the participant reached volitional exhaustion. Participants were verbally encouraged to provide a maximal effort during the final stages of the test. Throughout the test, pulmonary gas exchange was measured using a metabolic cart (Parvo TrueOne, UT, USA) which was calibrated for gas and volume prior to each test using alpha grade gases and known volumes. The $\dot{V}O_{2\ peak}$ was defined as the highest 30 s average $\dot{V}O_2$ attained during the test. The HR was monitored using short-range telemetry (Polar s610, Kemplele, Finland) and the peak (HR_{peak}) determined as the highest HR attained during the test.

6.2.3.2 30-15 intermittent fitness test

The $30\text{-}15_{IFT}$ was administered as previously validated by Buchheit et al. (2008). The test was performed outdoors on an artificial grass surface. Marker cones were placed 40 m apart to set the running distance and 3 m zones were set at both ends and in the middle of the running interval. Participants completed shuttle runs between the cones for 30 s interspersed with 15 s passive recovery periods. Velocity was set at 8 km·hr^{-1} for the first 30 s run and increased by 0.5 km·hr^{-1} every 45 s stage thereafter. Interval speed was dictated by long auditory beep signals, whereas to govern pace short beep signals sounded to indicate when participants had to pass through each 3 m zone. The test was terminated when participants could no longer maintain the imposed running speed. The velocity attained during the last completed stage was taken as the final running speed (V_{IFT}) and used for individualisation of prescription for the high-intensity (i.e. 100% V_{IFT}) running bouts.

6.2.3.3 Small-sided games

A non-sport specific SSG "bucketball" was implemented throughout the study (Harrison et al., 2013). Bucketball is a two-sided game during which the main objective is to score a goal in the opposing team's bucket. Running with the ball is permitted and it may be passed from the hands, player to player, in any direction. Possession is maintained until the ball is dropped, or goes out of play. To score, the player must be outside of the bucket circle. Play resumes by the team that conceded a goal from the top of their bucket circle. Passes may be intercepted and possession may be stolen from the player with the ball by the opposition dislodging it from their hands however the attacking player cannot be held in any way by the defender. Players were familiarised with SSGs in the first two weeks of the study and ranked for technical skill and game intelligence by an experienced coach, and for fitness based on their V_{IFT}, to allocated players into balanced teams. This process was also used to allocate man marking partners for game format three (Table 6.1). Players were selected on the same team against the same opponents as often as possible. Games were played outdoors on an artificial grass surface in temperate conditions (16-20 °C, 64-90 %rH) and coach encouragement was given to players throughout.

6.2.4 Physiological responses

The HR of each player was recorded during each SSG at 5 s intervals using radiotelemetry (Polar s610, Kemplele, Finland). The HR_{mean} and HR_{peak} of all SSGs were determined. Relative exercise intensity of each SSG was expressed as percent HR_{peak} (as determined from the incremental test) and classified into four intensity zones: zone 1 (<75% HR_{peak}), zone 2 (75-84% HR_{peak}), zone 3 (85-89% HR_{peak}), and zone 4 (>90% HR_{peak}) (Gore, 2000).

6.2.5 Time-motion characteristics

During all SSGs players wore a portable global positioning system (GPS) unit (VX Sport 220, Visuallex Sport International, Wellington, New Zealand) located at the posterior side of the upper torso and held in place using a customised vest design. The GPS system sampled at 4 Hz and provided speed, distance and body load data. Speed data was classified into four zones: standing or walking (0-6.9 $km \cdot hr^{-1}$), jogging (7-12.9 $km \cdot hr^{-1}$), running (13-17.9 $km \cdot hr^{-1}$), and sprinting (>18 $km \cdot hr^{-1}$) (Hill-Haas, Dawson, et al., 2009). GPS technology has been shown to offer a valid and reliable way of measuring distance and movement speed by players involved in team sports (Jennings et al., 2010).

6.2.6 Physical and perceptual responses

Body load provides a measure of total stress resulting from accelerations, decelerations and changes of direction (Boyd, Ball, & Aughey, 2011). Briefly, body load was derived from the square root of the sum of the squared instantaneous rate of change in acceleration in each of the three vectors (*x*-, *y*-, and *z*-axes) and expressed as body load per min for each SSG. The body load variable has previously been established as highly reliable (Coefficient of variation: < 2%) (Boyd et al., 2011). Ratings of perceived exertion (RPE) were determined using the 6-20 linear Borg scale (Borg, 1982) at the completion of each SSG. Players were asked to rate their perceived exertion on the entire game rather than at the time of rating. The typical error of RPE for SSGs has been shown to be 1-2 units (Hill-Haas et al., 2008).

6.2.7 Technical skill executions

All SSGs were recorded using a high-speed digital video camera positioned overhead (Canon G11, Canon Inc, Tokyo, Japan) and post-game notation analysis was undertaken to determine each player's skill executions. The following executions were quantified by an experienced technical analyst: number of involvements, total and successful receives and total and successful passes. A successful pass was defined as one that was either caught or able to be caught by a player on the same team.

6.3 Statistical analyses

Data were log-transformed to reduce bias due to nonuniformity of error and analysed using a customised spreadsheet (Hopkins, 2006b). Differences between SSGs formats for physiological and perceptual responses, time-motion characteristics and skill executions were evaluated using the effect size (ES) statistic with upper and lower 90% confidence intervals (CI) and percentage change to determine the magnitude of any difference displayed. The chances that the true (population) differences are substantial were assessed using 0.2 standardised units (change in mean divided by the between subject SD) (Hopkins, 2006b). The magnitude of difference was classified as small 0.2 to 0.6, moderate 0.6 to 1.2, large 1.2 to 2.0, and very large 2.0 to 4.0. Effects with less certainty were classified as trivial, and where the ± 90% CI of the ES crossed the boundaries of -0.2 and 0.2, the effect was reported as unclear.

6.4 Results

Descriptive data (mean ± SD) for the various SSG formats are presented in Table 6.2. Differences between SSG formats for physiological and perceptual responses and time-motion characteristics are presented in Table 6.3. Differences in technical executions between bucketball (BB), bucketball with 3 s permitted in possession (BB^{3S}) and bucketball with man-on-man marking (BB^{MM}) are presented in Table 6.4.

6.4.1 Physiological responses

Percent HR_{peak} and time spent ≥90% HR_{peak} for BB substantially exceeded all other modified SSG formats. A substantial difference was also observed between BB^{3S} and BB^{HR} for time spent ≥90% HR_{peak} (Table 6.2).

6.4.2 Time-motion characteristics

Total distance travelled between 13-17.9 $km \cdot hr^{-1}$ and ≥18 $km \cdot hr^{-1}$ during BB^{HR} substantially exceeded all other SSG formats. A substantial difference was also present between BB^{3S} and BB^{MM} for total distance travelled ≥18 $km \cdot hr^{-1}$.

Table 6.2 – Means (± SD) for physiological and perceptual responses, time-motion characteristics and technical executions for small-sided game (SSG) formats.

	BB	BB^{3S}	BB^{MM}	BB^{HR}
$\%HR_{peak}$ ($b \cdot min^{-1}$)	89.6 ± 1.5	88.1 ± 2.2	88.4 ± 1.8	88.3 ± 1.8
Time spent ≥90% HR_{peak} (s)	569.8 ± 149.1	381.4 ± 241.9	418.4 ± 208.6	490.7 ± 108.8
Total distance (m)	1671.0 ± 141.1	1575.3 ± 182.5	1613.0 ± 175.8	1980.4 ± 106.6
Total distance at 13-17.9 $km \cdot hr^{-1}$ (m)	331.2 ± 110.8	308.6 ± 105.7	297.5 ± 113.3	624.3 ± 137.5
Total distance ≥18 $km \cdot hr^{-1}$ (m)	64.5 ± 55.1	45.5 ± 27.7	63.3 ± 28.3	454.8 ± 245.0
RPE	14.2 ± 0.8	12.4 ± 2.8	13.8 ± 0.6	15.9 ± 1.3
Body load ($au \cdot min^{-1}$)	284.7 ± 30.2	273.7 ± 35.9	290.3 ± 56.5	308.8 ± 48.7
Total involvements	26.2 ± 4.0	32.0 ± 6.3	23.5 ± 7.5	10.9 ± 3.9*
Total Receives	24.5 ± 6.8	37.3 ± 5.9	24.6 ± 6.0	11.5 ± 3.4*
Effective receives (%)	88.2 ± 7.2	92.2 ± 3.3	92.7 ± 3.7	92.1 ± 7.8 *
Total passes	26.3 ± 3.9	32.5 ± 5.6	23.8 ± 7.6	10.8 ± 3.8*
Effective passes (%)	97.1 ± 3.4	96.5 ± 4.3	97.1 ± 2.9	98.0 ± 3.7*

Note: BB, bucketball; BB^{3S}, bucketball 3 seconds; BB^{MM}, bucketball man of man; BB^{HR}, bucketball high-intensity running; TD, total distance; RPE, ratings of perceived exertion;, * = data for 8 min of SSG play.

6.4.3 Physical and perceptual responses

Body load was substantially higher for BB^{HIR} compared to all other SSG formats, and was substantially lower for BB^{3S} compared to both BB and BB^{MM}. Means (± SD) for body load for all SSG formats including separation of the game and running components during BB^{HR} is presented in Figure 6.2. For BB^{HR} body load was substantially higher during the high-intensity running bouts compared to BB, BB^{3S} and BB^{MM} SSG formats. For the games component, body load was substantially less than all SSG formats. RPE for BB^{HR} substantially exceeded all other SSG formats. Players RPE were also lower for BB^{3S} compared to BB. Means (± SD) for $\%HR_{peak}$ for all SSG formats including separation of the game and running components during BB^{HR} is presented in Figure 6.1.

Table 6.3 – Percentage difference, effect size (90% CI), and qualitative descriptor for physiological and perceptual responses, time-motion characteristics and player load between small-sided game (SSG) formats

	Difference (%)	ES (90% CI)	Qualitative descriptor	Difference (%)	ES	Qualitative descriptor
		%HR$_{peak}$ (b·min^{-1})			**Total Distance at 13-17.9 km·hr^{-1} (m)**	
BB – BB^{3S}	↓1.8	-0.73 (-1.26, -0.21)	Moderate	↓8.2	-0.19 (-0.50, 0.13)	Trivial
BB – BB^{MM}	↓1.4	-0.55 (-0.98, -0.13	Small	↓11.8	-0.27 (-0.66, 0.12)	Trivial
BB – BB^{HR}	↓2.0	-0.81 (-1.4, -0.22)	Moderate	↑76.5	1.23 (0.72, 1.75)	Large
BB^{3S} – BB^{MM}	↑0.5	0.22 (-0.66, 1.08)	Unclear	↓4.0	-0.09 (-0.24, 0.07)	Trivial
BB^{3S} – BB^{HR}	↓0.3	-0.11 (-1.23, 1.01)	Unclear	↑88.2	1.37 (0.82, 1.93)	Large
BB^{MM} – BB^{HR}	↓0.4	-0.16 (-0.16, -1.0)	Unclear	↑99.3	1.5 (0.89, 2.10)	Large
		Time spent ≥90% HR$_{peak}$ (s)			**Total Distance ≥18 km·hr^{-1} (m)**	
BB – BB^{3S}	↓47.3	-0.97 (-1.64, -0.30)	Moderate	↓19.7	-0.26 (-0.77, 0.24)	Unclear
BB – BB^{MM}	↓33.6	-0.62 (-1.12, -0.12)	Moderate	↑11.6	0.13 (-0.46, 0.73)	Unclear
BB – BB^{HR}	↓18.8	-0.32 (-0.53, -0.10)	Moderate	↑627.9	2.39 (1.89, 2.89)	Very large
BB^{3S} – BB^{MM}	↑26.2	0.35 (-0.67, 1.37)	Unclear	↑66.1	0.61 (0.03, 1.19)	Moderate
BB^{3S} – BB^{HR}	↑61.8	0.73 (-0.22, 1.67)	Moderate	↑806.5	2.65 (2.37, 2.94)	Very large
BB^{MM} – BB^{HR}	↑23.3	0.32 (-0.42, 1.05)	Unclear	↑552.3	2.26 (1.93, 2.59)	Very large
		Body load			**RPE**	
BB – BB^{3S}	↓4.3	-0.24 (-0.65, 0.17)	Small	↓15.4	-0.86 (-1.70, -0.02)	Moderate
BB – BB^{MM}	↓0.5	-0.03 (-0.72, 0.67)	Unclear	↓2.8	-0.14 (-0.39, 0.10)	Unclear
BB – BB^{HR}	↑8.0	0.42 (-0.03, 0.87)	Small	↑12.4	0.60 (0.28, 0.92)	Moderate
BB^{3S} – BB^{MM}	↑4.8	0.26 (-0.10, 0.61)	Small	↑14.9	0.71 (-0.31, 1.74)	Unclear
BB^{3S} – BB^{HR}	↑12.8	0.66 (0.40, 0.92)	Moderate	↑34.2	1.51 (0.44, 2.58)	Large
BB^{MM} – BB^{HR}	↑8.5	0.45 (-0.14, 1.03)	Small	↑15.0	0.72 (0.46, 0.97)	Moderate

Note: ES, effect size; CI, confidence interval; BB, bucketball; BB^{3S}, bucketball 3 seconds; BB^{MM}, bucketball man of man; BB^{HR}, bucketball high-intensity running; TD, total distance; RPE, ratings of perceived exertion; BL, body load. The magnitude of difference was classified as small 0.2 to 0.6, moderate 0.6 to 1.2, large 1.2 to 2.0, and very large 2.0 to 4.0. Effects with less certainty were classified as trivial, and where the ± 90% CI of the ES crossed the boundaries of -0.2 and 0.2, the effect was reported as unclear.

6.4.4 Technical skill executions

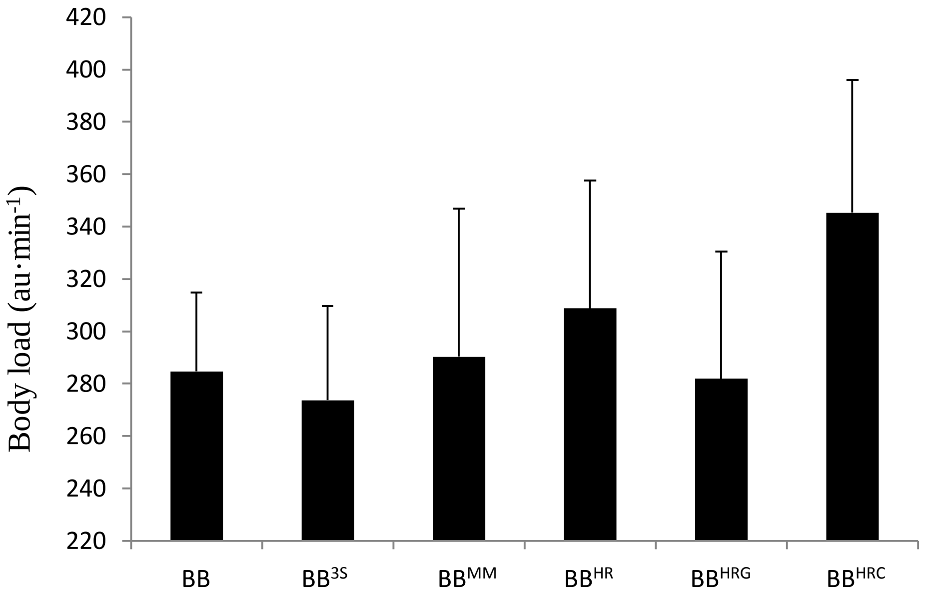
Number of ball involvements, total passes and receives for BB^{3S} substantially exceeded all other SSG formats with moderate to large ES. Substantial differences for involvements and total receives were present between BB and BB^{MM} and between BB and BB^{HR}. Differences in % successful passes were observed between BB and the remaining SSG formats. No differences existed between SSG formats for % successful receives.

Table 6.4 – Percentage difference, effect size (90% CI), and qualitative descriptor for technical skill executions between small-sided game (SSG) formats

	Difference (%)	ES (90% CI)	Qualitative descriptor	Difference (%)	Effect size	Qualitative descriptor
		Involvements / min			**Total passes / min**	
BB – BB^{3S}	↑21.1	0.56 (0.15, 0.96)	Small	↑56.2	1.48 (0.89, 2.08)	Large
BB – BB^{MM}	↓13.9	-0.44 (-0.96, 0.08)	Small	↑1.3	0.04 (-0.65, 0.74)	Unclear
BB – BB^{HR}	↓23.5	-0.78 (-1.52, -0.04)	Moderate	↓5.5	-0.19 (-0.84, 0.46)	Unclear
BB^{3S} – BB^{MM}	↓28.9	-1.00 (-1.46, -0.54)	Moderate	↓35.2	-1.44 (-2.04, -0.85)	Large
BB^{3S} – BB^{HR}	↓36.9	-1.34 (-1.83, -0.85)	Large	↓39.5	-1.67 (-2.24, -1.10)	Large
BB^{MM} – BB^{HR}	↓11.2	-0.34 (-1.0, 0.31)	Unclear	↓6.7	-0.23 (-1.0, 0.54)	Unclear
		% successful passes			**Total receives / min**	
BB – BB^{3S}	↑4.8	0.60 (-0.06, 1.25)	Moderate	↑23.0	0.62 (0.23, 1.01)	Moderate
BB – BB^{MM}	↑5.4	0.66 (-0.11, 1.44)	Moderate	↓13.1	-0.42 (-0.94, 0.10)	Small
BB – BB^{HR}	↑4.8	0.59 (-0.76, 1.84)	Small	↓22.2	-0.75 (-1.52, 0.01)	Moderate
BB^{3S} – BB^{MM}	↑0.5	0.07 (-0.19, 0.33)	Trivial	↓29.3	-1.04 (-1.55, -0.53)	Moderate
BB^{3S} – BB^{HR}	↓0.1	-0.01 (-0.76, 0.75)	Unclear	↓36.7	-1.37 (-2.0, -0.74)	Large
BB^{MM} – BB^{HR}	↓0.8	-0.10 (-0.89, 0.69)	Unclear	↓10.5	-0.33 (-1.05, 0.38)	Unclear
		% successful receives				
BB – BB^{3S}	↓0.7	-0.16 (-0.97, 0.65)	Unclear			
BB – BB^{MM}	↔0.0	-0.01 (-0.60, 0.59)	Unclear			
BB – BB^{HR}	↓0.5	0.11 (-0.72, 0.94)	Unclear			
BB^{3S} – BB^{MM}	↑0.7	0.14 (-0.36, 0.65)	Unclear			
BB^{3S} – BB^{HR}	↑2.3	0.51 (-0.45, 1.46)	Unclear			
BB^{MM} – BB^{HR}	↑1.2	0.27 (-0.58, 1.12)	Unclear			

Note: ES, effect size; CI, confidence interval; BB, bucketball; BB^{3S}, bucketball 3 seconds; BB^{MM}, bucketball man of man; BB^{HR}, bucketball high-intensity running.

a)



b)

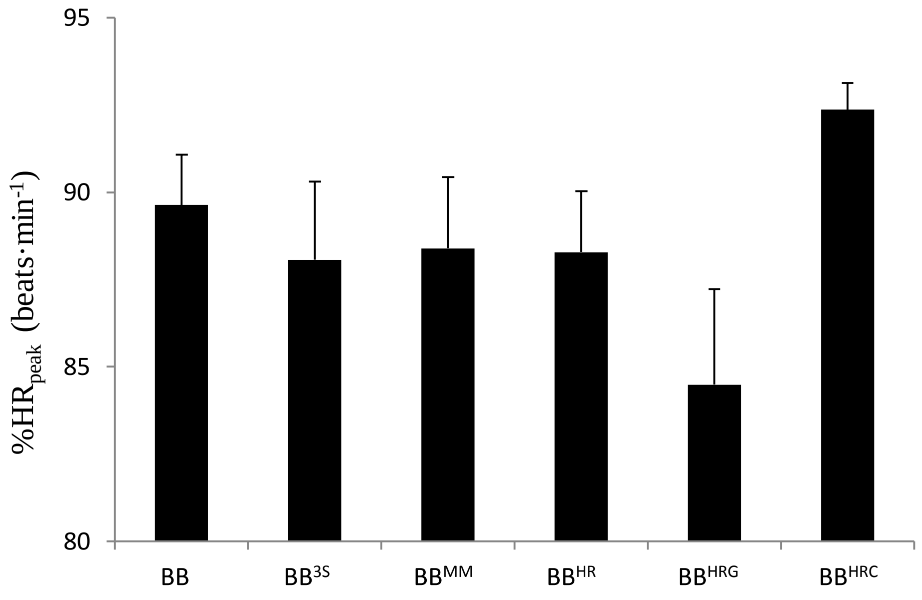


Figure 6.1. a) Body load, and b) $\%HR_{peak}$ (mean ± SD) for SSG formats.

Where: BB, bucketball; BB^{3S}, bucketball 3 seconds; BB^{MM}, bucketball man on man; BB^{HR}, bucketball high-intensity running; BB^{HRG}, bucketball high-intensity running games (1st and 3rd quarter only); BB^{HRC}, bucketball high-intensity running conditioning (2nd and 4th quarter only).

6.5 Discussion

It is common for team sport coaches of young players (>14 years) to modify SSG playing rules in an effort to control exercise intensity, or develop particular technical or tactical outcomes. However, while SSGs are frequently used in practice, a lack of scientific evidence exists to quantify its actual effects on physical and technical skill executions. To address this, the present study sought to systematically examine the effects of common rule modifications on the physiological responses, time-motion characteristics and technical executions during a non sport-specific SSG in young athletes. Our results demonstrate that simple manipulations to game rules and the addition of high-intensity running blocks are effective ways to bring about substantial changes in the internal and external load, the speed of movement, as well as the perceptual and technical demands of SSGs.

6.5.1 Physiological responses

To our knowledge this study is the first study to investigate the effect of modifying SSG play in young (<14 years) team sport athletes by manipulating games rules. For young athletes, the simultaneous development of physical and technical abilities would seem desirable. In this regard, SSGs provide an opportunity to develop aerobic fitness while at the same time challenge athletes technically and tactically to create an enjoyable training environment. To date, modifying SSG rules has predominantly been examined in adult (Dellal, Chamari, et al., 2011; Dellal, Lago-Penas, et al., 2011; Gabbett, 2012) and adolescent (Gabbett et al., 2010; Hill-Haas et al., 2010; Ngo et al., 2012) populations. The practical use and effectiveness of rule modifications for less mature athletes is unknown.

With respect to internal load in the present study, all three game variations (BB^{3S}, BB^{MM} and BB^{HR}) substantially lowered $\%HR_{peak}$ compared to SSGs with no rules changes (BB). In addition, time spent $\geq 90\%\ HR_{peak}$ was reduced with rule modification and the addition of high-intensity running blocks (Table 6.2). Interestingly, these results are in contrast to previous studies involving adolescent soccer players that reported an increase (Ngo et al., 2012) or no difference in exercise intensity (Hill-Haas et al., 2010; Sampaio et al., 2007) when examining man-on-man marking and inclusion of sprint running respectively, suggesting that similar rule modifications may not effect exercise intensity similarly for different types of SSGs and age groups. It is possible that a decrease in intensity during BB^{3S} and BB^{MM} SSGs observed in the present study may have resulted from higher cognitive load associated with increased technical skill executions (Table 6.3), coupled with limited game intelligence and decision making ability to maintain high intensity during play. However, since we did not measure cognitive load directly, further research is required to confirm this.

6.5.2 Time-motion characteristics

Total distance travelled at 13-17.9 and ≥18 $km \cdot hr^{-1}$ were substantially further compared to other SSGs (88-110% and 600-900%, respectively) when high-intensity running bouts were added to SSGs (Table 6.2). Consequently, is appears possible to significantly increase the speed that players are moving at with the inclusion of 'artificial' work (i.e. generic exercise prescribed over and above what is inherent to SSG play). This observation is in agreement with a previous study using adolescent soccer players, which reported a 39-54% increase in higher speed running (>13 $km \cdot hr^{-1}$) when repetitions of 'sprint the widths/jog the lengths' were added to SSGs (Hill-Haas et al., 2010). The significant difference in percent changes between the two studies is most likely due to the difference in high-intensity running protocols implemented. In the present study, a substantial increase in total distance ≥18 $km \cdot hr^{-1}$ was also reported for BB^{MM} compared to BB^{3S}. A possible explanation for this finding is that during the "man-on-man" SSGs when an attacking phase transitioned to defence, players caught out of position were forced to track their partner quickly at high speeds. Furthermore, “man-on-man” defensive tactics, as opposed to a zone defence, may have forced players to attack with rapid bursts of speed to break away from their opponent (Dellal, Chamari, et al., 2011; Ngo et al., 2012).

6.5.3 Physical and perceptual responses

Body load is an accelerometer-derived measured of external load, and has been associated with locomotor activity during team sport (Boyd, Ball, & Aughey, 2013). Our results demonstrated that body load was higher (8-13%) during BB^{HR} compared to all other game formats. This finding presumably relates to the increase in distance travelled at higher speeds during this SSG format. Three-dimensional body load has been suggested to be largely determined by foot strikes and forward accelerations from running (Boyd, Gallagher, Ball, Stepto, & Aughey, 2010). To examine the BB^{HR} SSG format more closely, we separated the SSG (1st and 3rd quarter) and high-intensity running conditioning (2nd and 4th quarters) components for $\%HR_{peak}$ and body load (Figure 6.1). This allowed us to more accurately assess the demands of the different exercise modes (i.e. game play versus running) during the entire SSG. The results revealed higher internal (physiological) and external (movement) loads for the high-intensity running bouts compared to the other SSG formats. Interestingly however, during the SSGs sections of BB^{HR}, internal and external loads were lower compared to other SSG formats. It is possible that players may have employed a pacing strategy during the SSGs periods in anticipation of the high-intensity running bouts to follow. A decrease in the tempo of the games would have reduced the physiological responses of players. Alternatively, heightened fatigued following the first block of high-intensity running caused by high internal and external loads may simply have decreased the player’s performance capacity in the third quarter. As a result, it may have been treated as a ‘recovery’ period by players in preparation for the second bout of high-intensity running.

The perceived demand of the SSGs was higher for BB compared to both BB^{3S} and BB^{MM}, but lower than that reported for BB^{HR}. Interestingly, these differences were only partly aligned to the internal load experienced by the players. The largest difference reported for body load (BB^{3S}-BB^{HR}; ES = 0.66), also had the largest difference in RPE (ES = 1.51). These results suggest that the perceptual response may have been influenced by external load of the various SSG formats more so than internal load (Lovell, Sirotic, Impellizzeri, & Coutts, 2013).

6.5.4 Technical skill executions

When players were restricted to the “3 seconds on the ball” rule, a substantial increase in technical executions including the number of involvements, passes and catches were reported (Table 6.3). This result was not surprising as players were forced to pass the ball at more regular intervals. Technical executions were also increased when ball touches were restricted in a previous study investigating SSGs in soccer players (Dellal, Lago-Penas, et al., 2011). Therefore, the use of a time constraint on possession for increasing technical executions during a non sport-specific SSG in young athletes appears to be warranted.

While increasing the number of possessions and passes would be beneficial for individual skill development, the quality of passing should also be considered. Despite being similar to previous work (Harrison et al., 2013), the percent of successful passes during BB in the present study was lower than for BB^{3S} and BB^{MM} SSG formats (Table 6.2). This finding is possibly due to the higher internal and external loads experienced by players during the non-modified BB format, which may have affected passing accuracy. Despite potential benefits of higher external loads elicited by the inclusion of high-intensity running bouts during SSG training, fewer technical executions during subsequent game play were observed (Table 6.4). Presumably this was a consequent of fatigue brought about by the more work completed by players during the high-intensity running bouts. In contrast, no difference was observed in the effectiveness of receiving a pass between BB formats. It is possible that higher intensities and body load have a greater impact on the quality of technical executions in possession rather than out of possession during SSGs in young athletes, however additional research is required to explore this further.

6.6 Conclusion

We have demonstrated, for the first time, the effects of simple rule modifications on physiological responses, time-motion characteristics, physical and perceptual responses and technical executions during a non sport-specific SSG in young athletes. Our results showed that higher intensities were achieved during SSGs with no adjustment to the rules. However, the manipulation of SSGs rules led to an increase in the quality and quantity of technical skill executions and increased the distance players travelled at higher running speeds. Therefore, when prescribing SSGs the decisions of the coach or sport scientist should be guided by the training adaptations that are most desired. In addition, when high-intensity individualised running bouts were included in SSGs, the internal and external work players experienced substantially increased. However, this decreased exercise intensity and the number of technical skills players executed in subsequent game play. Clearly, physiological, perceptual, movement speed, and technical skill benefits are inherent in SSG rule modification and with the inclusion of high-intensity running in young athletes. Practically, such findings will permit the refinement of training prescription in young athletes and assist coaches with achieving their desired training outcomes.

Chapter 7: Aerobic fitness for young athletes: Small-sided games or high-intensity interval training?

7.1 Introduction

Aerobic fitness is a critical component of fitness for elite players in a wide range of team sports (Helgerud et al., 2001; Hoff et al., 2002; Loftin et al., 1996). For young players, a high aerobic fitness can assist with optimising development by increasing an individual's capacity to withstand and recover from high physiological training loads (Bishop & Spencer, 2004), improving concentration to deal with technical and tactical challenges under fatigue (Vänttinen et al., 2010), and increasing the likelihood of a higher level of aerobic fitness in young adulthood (Janz & Mahoney, 1997). Accordingly, the ongoing development of aerobic fitness in young team sport athletes is an important consideration for coaches and conditioning specialists.

Attainment of a training stimulus at or near peak oxygen uptake (VO_{2peak}) is considered a requirement to optimise aerobic adaptation (Midgley & MacNaughton, 2006). In team sports, this intensity has traditionally been targeted using high-intensity interval training (HIIT) (Balabinis, Psarakis, & Moukas, 2003; Dupont et al., 2004; Helgerud et al., 2001). Although this training approach may be effective, such training protocols require strict adherence and can be perceived to be unpleasant by players. Furthermore, to achieve optimal gains, dedicated physical training time is required which often reduces the time spent acquiring important technical and tactical skills during other practices. To avoid this situation, the use of small-sided games (SSGs) has been proposed as an efficient and effective training method to simultaneously improve aerobic fitness and technical and tactical abilities (Buchheit, Laursen, et al., 2009; Hill-Haas, Coutts, et al., 2009).

Previous research comparing the respective long term effects of interval training and SSGs on performance are limited (Buchheit, Laursen, et al., 2009; Hill-Haas, Coutts, et al., 2009; Impellizzeri et al., 2006; Reilly & White, 2004). Some researchers have reported improvements in various measures of aerobic fitness but no training type effect. Specifically, Impellizzeri et al. (2006) compared 12 weeks of traditional interval training (e.g. 4 x 4 min at 90-95% heart rate max (HR_{max}), separated by 3 min of active recovery at 60-70% HR_{max}) with SSGs training, carefully matched for duration and intensity, in adolescent (17.2 ± 0.8 years) professional soccer players. Their results demonstrated similar increases in VO_{2peak} and sport-specific endurance (Yo-Yo Intermittent Recovery Test Level 1; YYIRT1) following interval and SSG training. In another study, Buchheit et al. (2009) reported that interval and SSGs training matched for exercise intensity were similarly effective at increasing the final running velocity during the 30-15 intermittent fitness test (5.6% and 6.5%, respectively) following 10 weeks of training in adolescent (15.2 ± 0.9 years) handball players (Buchheit, Laursen, et al., 2009). While both studies demonstrated high levels of internal validity through the use of carefully prescribed training loads, a more recent study by Hill-Haas et al. (2009) prioritised high external validity in their experimental approach by including coach prescribed training regimes. Their study revealed no change in VO_{2peak} or the distance travelled during the multistage fitness test for either SSG or classic training in soccer players (14.6 ± 0.9 years). However, an increase in YYIRT1 performance was observed following both types of training (Hill-Haas, Coutts, et al., 2009), suggesting that the ability to perform intense intermittent exercise is dependent on various physical capacities.

To date, research investigating improving aerobic fitness has focused primarily on quantifying the effects of sport-specific SSGs training on physical performance in relatively skilled players. There has been little consideration of younger athletes (i.e. < 14 years) who may participate in a variety of sports involving upper and lower body skills, and are likely to be less technically skilled than their older, more experienced counterparts. Similarly, most studies have adopted forms of SSGs that are closely matched to specific sports. However, a recent study reported that a simple non sport-specific SSG involving fundamental skills (i.e.

catch and pass) to control possession elicited higher levels of intensity compared with soccer-specific SSGs during play in young players (Harrison, Gill, Kinugasa, & Kilding, In Press), and may have the potential for inducing worthwhile training adaptations in young athletes across a wide range of team sports if prescription parameters are optimised (Harrison et al., 2013, In Press). Indeed, given the increasing popularity of SSGs in training, further experimental evidence investigating various game specifications is required to determine their benefits to aerobic fitness performance in young team sport athletes.

From a developmental perspective, SSGs permit the simultaneous development of technical skill and tactical awareness, and adherence by young athletes is likely to be high given the inherent enjoyment with game related exercise (Harrison et al., 2013). However, to induce adaptation for improving aerobic fitness, sufficient training intensities must be reached and maintained (Helgerud et al., 2007). Therefore, a training regime combining SSGs and HIIT exercise may be beneficial. Furthermore, for players who have not yet specialised in any particular sport, the most effective training prescription may be one that assures a high physiological load but also provides an opportunity for players to maximise and refine fundamental game technical skills (Harrison et al., 2013). Therefore the purpose of this study was to compare the effects of combining high-intensity intermittent training (HIIT) and SSGs training versus SSGs training alone on aerobic fitness performance characteristics in young team sport athletes.

7.2 Methods

7.2.1 Experimental approach

A two-group, matched, randomised, experimental design was used in this study. Participants were divided into two training groups that performed mixed high-intensity intermittent running and SSG training (MT; n = 13) or SSGs only (GT; n = 13). Participants within each group were balanced according to their maturation, initial fitness level, as well as physical skill and game intelligence ability (Buchheit, Laursen, et al., 2009). Following an appropriate familiarisation period, a range of physical performance tests were completed two weeks prior to and following a six week training period. To aid standardisation, assessments were performed at the same time of day, to control for circadian and training-related fluctuations in performance. For inclusion in post testing analysis participants were required to complete >85% of all training sessions.

7.2.2 Participants

Twenty-six young male (13.9 ± 0.4 years) team sport players were recruited to participate in this study. Participants mean age from peak height velocity (PHV) was calculated using a non-invasive and practical method based upon anthropometric variables (Mirwald et al., 2002). All participants were involved in at least two training sessions per week, plus a game in a regional school competition. Participants and their parents (or guardians) were informed of the procedures and were required to give written informed consent and assent respectively. This study was approved for experimentation involving human subjects by the Auckland University of Technology Ethics Committee.

7.2.3 Procedures

7.2.3.1 Incremental treadmill running test

Peak oxygen uptake ($\dot{V}O_{2peak}$) was determined during an incremental treadmill running test on a motorised treadmill (h/p/cosmos, Germany) (Armstrong et al., 1999). Briefly, after a 3 min warm-up at 6 $km \cdot hr^{-1}$ and 1% gradient, the treadmill speed was set at 10 $km \cdot hr^{-1}$ for the initial 3 min stage and increased to 12 $km \cdot hr^{-1}$ for the next stage. Thereafter, treadmill speed was held constant at 12 $km \cdot hr^{-1}$ and the gradient increased by 2.5% every 3 min until the participant reached volitional exhaustion. Participants were verbally encouraged to provide a maximal effort during the final stages of the test. Throughout the test, pulmonary gas exchange was measured using a metabolic cart (Parvo TrueOne, UT, USA) which was calibrated for gas and volume prior to each test using alpha grade gases and known volumes. The $\dot{V}O_{2\ peak}$ was defined as the highest 30 s average $\dot{V}O_2$ attained during the test. Heart rate was monitored using short-range telemetry (Polar s610, Kemplele, Finland) and the peak (HR_{peak}) determined as the highest HR attained during the test.

7.2.3.2 Intermittent Performance Test

The $30\text{-}15_{IFT}$ was administered as previously described by Buchheit et al. (2008). Briefly, on an outdoor artificial grass surface marker cones were placed 40 m apart to set the running distance. Participants completed shuttle runs between the cones for 30 s interspersed with 15 s passive recovery periods. Velocity was set at 8 $km.hr^{-1}$ for the first 30 s run and increased by 0.5 $km.hr^{-1}$ every 45 s stage thereafter. Interval time was dictated by long auditory beep signals, whereas to govern pace short beep signals sounded to indicate when participants had to pass through 3 m zones set at both ends and in the middle of the running interval. The test was terminated when participants could no longer maintain the imposed running speed. The velocity attained during the last completed stage was taken as the final running speed (V_{IFT}) and used to prescribe the HIIT. The reliable V_{IFT} (intraclass correlation coefficient = 0.96; typical error = 0.33 (95% confidence limits (CL) = 0.26 – 0.46 $km.hr^{-1}$) has been shown to be an accurate tool for individualizing intermittent shuttle running exercise (Buchheit, 2008).

7.2.3.3 Lower limb explosive power

Lower limb explosive power was assessed using a vertical counter movement jump (VCMJ). Jump height (cm) was collected with a portable plate (AMTI, ACP, Watertown, MA) using a sampling rate of 400 Hz. Participants performed three trials with approximately 30 s recovery between trials. For each jump participants were asked to keep their hands on their hips to isolate the lower limb musculature, eliminating the influence of the upper limb at the hip joint, and reducing the importance of skill and coordination. No specific instructions were given to the participants in regards to the depth or speed of the VCMJ. The VCMJ movement consisted of sinking and then jumping as high as possible in the ensuing concentric phase and landing on two feet. Jump height of the best two trials was averaged and the result recorded.

7.2.3.4 Speed

Sprint time was measured with a timing light system consisting of a dual-beam modulated visible red-light system with polarizing filters (Swift Performance, Southern Cross University, Australia) with timing gates set up at 0, 5, and 20 m. Players started in a split stance with the preferred leg forward 50 cm behind the starting line. No stepping backwards, rocking or any kind of stretch-shortening-cycle was allowed to gain momentum. A cone was placed at the 25 m line to ensure that the subjects passed the final gates at their maximal velocity. Average time of the best two trials was recorded.

7.2.4 Training intervention

Participants performed two specific training sessions per week, in addition to their usual training requirements, for six weeks. Training regimes followed a periodised plan that included overload and progression, and a short tapering period to maximise final performance. The MT regime consisted of one session a week of HIIT and one session per week of 3 vs. 3 SSGs training, whereas the GT training regime consisted of two sessions per week of 3 vs. 3 SSGs training (Table 7.1). The MT incorporated individualised shuttle running for 15 s work intervals at 90-95% of V_{IFT} separated by 15 s rest periods of passive recovery over a 35 m distance (Table 7.1). The non-sport specific SSG “bucketball” was implemented for SSGs training (Harrison et al., 2013) during which the main objective is to score a goal in the opposing team's bucket. Running with the ball is permitted and it may be passed from the hands, player to player, in any direction. Possession is maintained until the ball is dropped, or goes out of play. To score, the player must be positioned outside of the bucket circle. Play resumes by the team that conceded a goal from the top of their bucket circle. Passes may be intercepted and possession may be stolen from the player with the ball by the opposition dislodging it from their hands, but the attacking player cannot be held in any way by the defender. Players were familiarised with SSGs in the first two weeks of the study and ranked for technical skill and game intelligence by an experienced coach, and for fitness based on their V_{IFT}, to allocated players into balanced teams. Players were selected on the same team against the same opponents as often as possible. Games were played outdoors on a grass surface in temperate conditions (16-20 °C, 65-85 %rH) and coach encouragement was given to players throughout.

Table 7.1. Training interventions for small-sided games training (GT) and mixed training (MT) groups

Week	Session	GT	MT
1 – 2		Pre intervention testing and SSGs familiarisation	
3	1	16 min SSG	16 min SSG
	2	2 x [8 min SSG; 3 min PR]	2 x [16 x 15/15 @ 90% V_{IFT} – 3 min PR]
4	3	16 min SSG	16 min SSG
	4	2 x [8 min SSG; 3 min PR]	2 x [16 x 15/15 @ 93% V_{IFT} – 3 min PR]
5	5	18 min SSG	18 min SSG
	6	2 x [10 min SSG; 3 min PR]	2 x [20 x 15/15 @ 93% V_{IFT} – 3 min PR]
6	7	20 min SSG	20 min SSG
	8	2 x [10 min SSG; 3 min PR]	2 x [20 x 15/15 @ 95% V_{IFT} – 3 min PR]
7	9	22 min SSG	22 min SSG
	10	2 x [11 min SSG; 3 min PR]	2 x [22 x 15/15 @ 95% V_{IFT} – 3 min PR]
8	11	24 min SGG	24 min SGG
	12	2 x [8 min SSG; 3 min PR]	2 x [16 x 15/15 @ 95% V_{IFT} – 3 min PR]
9 – 10		Post intervention testing	

Note: SSG, small-sided game; PR, passive recovery; V_{IFT}, final running velocity in the 30-15 intermittent fitness test; 2 x [16 x 15/15 @ 90% V_{IFT} – 3 min PR], 2 sets consisting of sixteen 15 s runs at 90% of V_{IFT} interspersed with 15 s of passive rest, separated by 3 min of PR.

7.2.5 Training variables

During training the HR of each player was recorded at 5 s intervals using wireless ANT coded 2.4GHz digital straps (Suunto, Vantaa, Finland). Relative exercise intensity was expressed as percent HR_{peak} (as determined from the incremental test) (Gore, 2000). Ratings of perceived exertion (RPE) were determined using the 6-20 linear Borg scale (Borg, 1982) at the completion of each training session. Players were asked to rate their perceived exertion on the entire training session rather than at the time of rating. The typical error of RPE for SSGs has been shown to be 1-2 units (Hill-Haas et al., 2008). Quantification of global training load was obtained each week by multiplying training duration (min) by session RPE. Body load was assessed using portable global positioning systems (GPS) (VX Sport 220, Visuallex Sport International, Wellington, New Zealand) equipped with 3 axis accelerometers logged at 104Hz per channel. The GPS units were located at the posterior side of the upper torso of each participant and held in place using a customised vest design. Body load provides a measure of total stress resulting from accelerations, decelerations, and changes of direction (Boyd et al., 2011). Briefly, body load was derived from the square root of the sum of the squared instantaneous rate of change in acceleration in each of the three vectors (*x*-, *y*-, and z-axes) and expressed as body load·min^{-1} for each SSG. The body load variable has previously been established as highly reliable (CV: < 2%) (Boyd et al., 2011).

7.3 Statistical analysis

Simple group statistics are presented as means ± between-subject SDs. All data were log transformed to reduce nonuniformity of error, and the effects of the training intervention were derived by back transformation as percent changes (Hopkins, 2006a). Standardised changes in the mean of each measure were used to assess magnitudes of effects by dividing the changes by the between-player SD. Standardized changes of 0.00–0.19; 0.20–0.59; 0.60–1.19; and ≥1.20 were interpreted as trivial, small, moderate, and large effects, respectively. To make inferences about true (large-sample) value of an effect, the uncertainty in the effect was expressed as 90% CL. The effect was deemed unclear if its confidence interval overlapped the thresholds for small positive and negative effects (Batterham & Hopkins, 2006). Differences between training interventions for training load, heart rate and perception of effort were evaluated using the effect size (ES) statistic with upper and lower 90% CL and percentage change to determine the magnitude of any difference displayed.

7.4 Results

Five players did not meet the inclusion criteria for analysis due to lack of training adherence or injury, leaving 21 players for final analysis (mean ± SD: age, 13.9 ± 0.3 years; height, 166.1 ± 8.9 cm; body mass, 56.6 ± 9.8 kg; age from PHV, 0.46 ± 0.7 years).

7.4.1 Physical load and perceptual responses to training

Players completed 12 exercise sessions corresponding to 226 min of training. Moderate differences in training internal load were observed between the MT and GT group for $\%HR_{peak}$ (2.9 ± 1.9%) and time spent above $90\%HR_{peak}$ (41.4 ± 15.1%). A large difference (13.5 ± 3%) was observed between the MT group (363 ± 23 $au \cdot min^{-1}$) and the GT group (321 ± 20 $au \cdot min^{-1}$) for weekly body load. Typical HR and body load response of a player to a SSG and HIIT session are presented in Figure 7.1. A moderate to large difference between MT and GT was observed for global training load between regimes for weeks 1, 2, 3, 4 and 6 of training (ES = 0.65, 0.87, 1.02, 0.80 and 1.23, respectively).

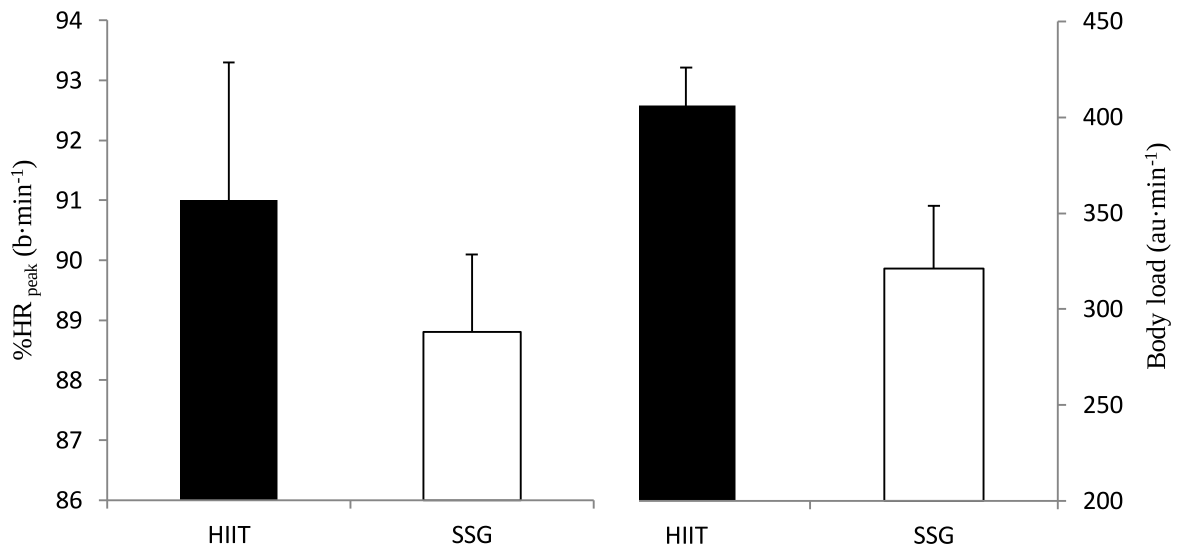


Figure 7.1. Typical heart rate (HR) and body load response of a player to a high-intensity interval training sessions (HIIT) and small-sided games (SSG) session.
AU, arbitrary units.

7.4.2 Changes in performance after training

Baseline data for all measures are presented in Table 7.2. Both groups were well matched with small between-group differences for VCMJ only. Inferences about the effect of each training regime are shown separately (pre-post percent change) and comparatively (GT vs. MT, percent effects) in Table 7.2. Both training regimes produced increases in V_{IFT}. Relative to changes in the GT group, the MT group produced moderate and small increases in relative $\dot{V}O_{2\ peak}$ (ml·kg·min^{-1}) and allometrically adjusted $\dot{V}O_{2\ peak}$ (ml·kg$^{-0.75}$·min^{-1}), respectively, and a small increase in V_{IFT}. The GT group produced a small decrease in 5 m sprint time, but trivial between-group differences were observed for 5 m and 20 m sprint and VCMJ.

Table 7.2. Pre and post testing values, percent change (mean ± SD) and percent effect (difference; ±90% confidence limits) in performance outcomes following 6 weeks of small-sided games training (GT) and mixed training (MT) in young team sport athletes

	GT			MT			
	Pre	Post	% Change	Pre	Post	% Change	MT – GT Difference (%)
$\dot{V}O_{2peak}$ (ml·kg·min^{-1})	55.9 ± 3.0	57.1± 3.5	1.6 ± 4.9 unclear	55.9 ± 2.5	59.0 ± 2.3	5.5 ± 3.3 large	3.3 ± 2.8 moderate
$\dot{V}O_{2peak}$(ml·kg$^{-0.75}$·min^{-1})	151.1 ± 8.1	157.6 ± 13.7	2.2 ± 7.4 unclear	153.5 ± 12.2	160.1 ± 11.0	5.8 ± 5.1 small	3.1 ± 2.8 small
V_{IFT} (km·h^{-1})	18.1 ± 1.3	19.1 ± 1.4	4.2 ± 5.5 small	18.4 ± 0.8	19.6 ± 0.7	6.6 ± 3.2 large	1.5 ± 2.1 small
5 m sprint time (s)	1.11 ± 0.08	1.06 ± 0.06	-5.1 ± 6.6 small	1.11 ± 0.06	1.10 ± 0.07	-1.1 ± 5.3 unclear	3.4 ± 6.6 trivial
20 m sprint time (s)	3.33 ± 0.27	3.24 ± 0.24	-2.7 ± 7.0 unclear	3.39 ± 0.21	3.35 ±0.22	-1.2 ± 5.6 unclear	1.5 ± 1.6 trivial
VCMJ (cm)	33.2 ± 6.2	33.8 ± 6.4	1.4 ± 18.5 unclear	29.4 ± 3.7	31.0 ± 5.7	4.7 ± 13.8 unclear	3.3 ± 6.4 trivial

Note: V_{IFT}, final running velocity in the 30-15 intermittent fitness test; VCMJ, vertical countermovement jump

7.5 Discussion

Recent evidence has identified SSGs as an alternative training modality to more traditional interval running for improving aerobic fitness characteristics in team sport players (Hill-Haas, Coutts, et al., 2009; Owen, Wong, Paul, & Dellal, 2012). However, while previous studies have concentrated on sport-specific SSGs in adults and youth (Buchheit, Laursen, et al., 2009; Hill-Haas, Coutts, et al., 2009; Impellizzeri et al., 2006) the present study is the first to investigate the effectiveness of training using a non sport-specific SSG to increase the aerobic fitness qualities in younger athletes. Furthermore, none have considered the combined effects of SSGs and HIIT. Our results show that while non sport-specific SSGs training and a combination of SSGs and HIIT training were both effective at increasing physical performance parameters in young team sport athletes, greater effects were seen following combined SSGs and HIIT.

7.5.1 Physical load and perceptual responses during training

Our results demonstrated that weekly player body load was higher for MT compared to GT. This finding was likely a consequence of a greater volume of faster movement speeds during the HIIT component of the MT. Previous research in Australian Football has shown that activities with higher running activity to be more physiologically demanding than those without (Boyd et al., 2010). In non-contact environments, body load is suggested to be largely determined by foot strikes and forward accelerations from running (Boyd et al., 2010). As literature assessing accelerometers in SSGs and HIIT training in young athletes is limited, further investigations are required to develop a greater understanding of how these devices can be used effectively.

The global training load was also substantially higher for MT compared to the GT. It is possible that a combination of a higher internal load (i.e. more time spent training above

90% HR_{peak}), time spent accelerating, and faster movement speeds during MT were responsible for our findings. A previous study investigating young soccer players showed that despite similar exercise intensities, perceived training load was higher during generic training that included traditional running exercise compared to SSG training (Hill-Haas, Coutts, et al., 2009). In contrast, a study comparing soccer SSGs and HIIT in young adults reported no difference in perceived training load between groups (Impellizzeri et al., 2006). Therefore, although internal load is likely to play a role in perceived training load, it is possible that external load may be more of a determining factor at high exercise intensities in younger athletes (Lovell et al., 2013).

7.5.2 Effects on maximal aerobic power and intermittent performance

In the present study, combining SSGs and HIIT was effective at improving aerobic power (~5%) whilst SSGs alone did not produce the same benefit. Given that exercise intensities of 90-95% of HR_{max} are required for significant increases in $\dot{V}O_{2peak}$ (Helgerud et al., 2007; Hill-Haas, Coutts, et al., 2009; Impellizzeri et al., 2006), this finding is likely a consequence of more time spent training >90% HR_{max} by players in the MT group compared to the GT group. In contrast to our results, a previous study comparing HIIT to SSGs training in elite adolescent soccer players, in which equal amounts of time were spent training above 90% HR_{peak}, reported similar increases in $\dot{V}O_{2peak}$ (7.4 and 6.4%, respectively) (Impellizzeri et al., 2006). The discrepancies between the results found in the present study and those by Impellizzeri et al. (2006) may be due to differences in training age, skill level or type of SSG format. Specifically, it is possible that an increased technical ability of older players, as a consequence of greater experience, allowed players during SSGs to attain sufficiently high intensities necessary to elicit changes in $\dot{V}O_{2peak}$. Indeed, equivalent amounts of time were spent above 90% HR_{peak} for HIIT and SSGs regimes (Impellizzeri et al., 2006). More recently, Hill-Haas et al. (2009) reported no change in the $\dot{V}O_{2peak}$ of junior elite soccer players after a 7 week pre-season training period (Hill-Haas, Coutts, et al., 2009). In this study, coach prescribed SSGs training and classic training (including some HIIT) were compared. Relatively little time was spent training >90% HR_{peak} during both training regimes compared to the present study, which may have resulted in insufficient stimulus to induce substantial aerobic adaptation. These findings suggest that accurate prescription of exercise intensity is a key factor influencing the change in $\dot{V}O_{2peak}$ in young team sport athletes.

Our results showed that both MT and GT were effective at improving V_{IFT} (7% and 4%, respectively). While our comparison of MT versus GT is novel, our findings parallel previous research investigating junior elite handball players that showed significant improvements in V_{IFT} following both SSGs and HIIT (Buchheit, Laursen, et al., 2009). Similarities in the findings are most likely due to carefully prescribed training loads in both studies. While both training regimes were effective at improving V_{IFT} in the present study, a larger increase was observed following MT. Significant relationships have been demonstrated between V_{IFT} and $\dot{V}O_{2peak}$, 10 m time and VCMJ suggesting that V_{IFT} accounts for multiple physiological variables associated with intermittent shuttle running (Buchheit, 2008). With this in mind, it is likely that the larger improvement in V_{IFT} in the MT group was a result of the larger increase in $\dot{V}O_{2peak}$. An increased aerobic response has been shown to increase metabolic efficiency during recovery, assisting with delaying the onset of fatigue (Tomlin & Wenger, 2001), which would have allowed for more high-intensity exercise to be sustained during the $30\text{-}15_{IFT}$. In addition, it is possible that the nature of the HIIT shuttle work during MT was specific to the performance requirements of the test of interest used in this study. In contrast, a small change in V_{IFT} was observed for the GT group despite no substantial change in $\dot{V}O_{2peak}$. It is possible that the faster V_{IFT} may have been associated with an improvement in acceleration ability. Our results partially confirm those reported in a previous training study (Buchheit, Laursen, et al., 2009). Collectively, these findings indicate that young team sport players can improve their 30-15_{IFT} performance with either a mixed training approach of SSGs and HIIT, or SSGs training alone, and provide further evidence that this test is sensitive to monitoring changes in player's ability to perform high-intensity, intermittent shuttle running ability (Buchheit, 2008).

7.5.3 Effects on speed and explosive power

Both training regimes were specifically designed to improve aerobic capacities, therefore it was not surprising that improvements in speed and power related variables were limited. However, our results demonstrated that 5 m time was decreased following GT but not MT. It is possible that this was due to the numerous short, fast movements inherent in SSGs training (Hill-Haas, Rowsell, et al., 2009). This finding is in contrast to previous research that reported no changes in speed and explosive power performance following either SSGs or HIIT (Buchheit, Laursen, et al., 2009; Hill-Haas, Coutts, et al., 2009). Differences in prior sprint ability or training history between our players and those utilised in previous studies may have affected the way in which players adapted to the training stimulus.

7.6 Conclusion

To conclude, we are the first to report the training effects of non sport-specific SSGs training compared to a combination of SSGs and HIIT on fitness and performance parameters in young athletes. The present study demonstrated that while both training regimes resulted in improvements in intermittent high-intensity running performance, the combination of SSGs training and HIIT was associated with greater gains. Furthermore, only the MT approach elicited improvement in aerobic power. Consequently, when development of aerobic power and intermittent running ability are a priority, the prescription of both SSGs and HIIT regimes should be adopted in young team sport athletes.

Chapter 8: Overall Discussion and Conclusions

8.1 Discussion

A comprehensive review of the literature highlighted a number of limitations in the current understanding of aerobic fitness development and trainability in young athletes. Principally, no studies have examined the effects of a non sport-specific SSG in young (<14 years) male athletes. In addition, there is a lack of research investigating and quantifying the effects of generic and specific aerobic training methods in young male team sport players. Accordingly, this thesis attempted to address these limitations. Subsequent discussion in this section articulates the main findings of this thesis, with respect to the studies undertaken and the wider literature.

Small-sided games provide an ideal training environment for enhancing aerobic fitness in team sport athletes (Buchheit, Laursen, et al., 2009; Hill-Haas, Coutts, et al., 2009). Furthermore, SSGs inherently cater for the development of movement, technical and tactical capabilities, which should also be considered when prescribing this method of exercise. Despite positive outcomes in a range of sport-specific studies in adults (Hoff et al., 2002; Impellizzeri et al., 2006; Little & Williams, 2006; Owen et al., 2011; Rampinini et al., 2007) and adolescents (Buchheit, Laursen, et al., 2009; Castagna et al., 2007; Hill-Haas et al., 2010; Hill-Haas, Dawson, et al., 2009), little is known about the specific formats of SSGs that best suit younger athletes who may participate in a variety of sports involving different technical skills.

8.1.1 Non sport-specific SSGs – optimisation of aerobic fitness development

8.1.1.1 Playing number and field size

Attainment of high exercise intensity is considered a crucial requirement to optimise aerobic adaptation during training (Da Silva et al., 2011; Hoff et al., 2002). Therefore, it should be the determining factor of the success of a particular SSG training regime for the purpose of increasing aerobic fitness. The findings of Chapter 3 illustrate the attainment of high heart rate intensities during 3 vs. 3 bucketball SSGs (Harrison et al., 2013) which may be useful for developing aerobic fitness in young players. In addition, mean % HR_{peak} response and time spent above 90% HR_{peak} during 3 vs. 3 bucketball were higher than in both 4 vs. 4 and 6 vs. 6 game formats. This effect was consistent with previous research examining the effect of altering player number in young soccer players (Katis & Kellis, 2009) and in adult and adolescent soccer and rugby league players (Dellal, Jannault, et al., 2011; Foster et al., 2010; Little & Williams, 2006; Rampinini et al., 2007). No difference in exercise intensity was reported between 4 vs.4 and 6 vs. 6 bucketball SSGs. This finding is in agreement with a similar study investigating young rugby league players (Foster et al., 2010), but is in contrast with studies investigating the alteration of SSG player number in adults that showed 4 vs. 4 to be more intense (Foster et al., 2010; Hill-Haas, Dawson, et al., 2009). Limitations in spatial awareness of the younger players compared to the more experienced older players, and variations in player movement accordingly, may have contributed to this finding. The overall quantity of technical executions (e.g. possessions, catches and passes) was higher when fewer players were involved on each team, but the quality of skill executions was unchanged between game formats. Results of GPS analysis demonstrated no difference in total distance travelled between game formats, but less distance at higher running speeds (i.e. above 13 $km \cdot hr^{-1}$) during 3 vs. 3 SSGs compared to 4 vs. 4 and 6 vs. 6 formats. Similar time-motion characteristics have been reported in previous research investigating adolescent soccer players (Hill-Haas, Dawson, et al., 2009). It is possible that increased possession during 3 vs. 3 bucketball, resulting from less players involved, requires players to slow down their running speeds for better control of technical outputs (Hill-Haas, Dawson, et al., 2009; Owen et al., 2011). Collectively, this evidence demonstrates that a 3 vs. 3 non sport-specific SSG elicits sufficient training stimulus to potentially improve aerobic fitness, while also allowing for more technical executions to be completed.

8.1.1.2 Non sport-specific versus sport-specific SSGs

Non sport-specific SSGs (i.e. bucketball) that require executions of fundamental technical skills to control possession (e.g. catch and pass) may allow players across a wide range of team sports to maintain a high level of intensity during play, and therefore be well suited to developing aerobic fitness in young athletes. In Chapter 4, the physiological responses between bucketball and soccer SSGs were compared. Exercise intensity (i.e. percent HR_{peak}) was higher during bucketball SSGs compared to soccer SSG equivalents (89.5% vs. 86.4% and 87.4% and 83.7%, for 3 vs. 3 and 6 vs. 6, respectively). Bucketball is arguably a less technical game than soccer due to the different skill requirements to control the ball. Therefore, bucketball may allow less-skilled younger players to control possession more effectively compared with soccer and therefore maintain a higher intensity during play. Indeed, the ability of players to maintain continuous play has been previously recognised as a key determinant of exercise intensity during SSGs, especially in soccer (Katis & Kellis, 2009). Interestingly, no differences were reported in ratings of perceived exertion (RPE) for 3 vs. 3 SSGs, despite a substantial difference in exercise intensity. This indicates that the use of RPE with young athletes may not always be an accurate indicator of physiological load, possibly due to insufficient experience to distinguish between relatively small yet important differences at high exercise intensities.

Comparisons of time-motion characteristics between bucketball and soccer SSGs were made in Chapter 4. Players travelled more total distance (4.9 ± 4.1% and 8.3 ± 6.6%) and distance at 7-12.9 $km \cdot hr^{-1}$ (14.5 ± 12.5% and 14.9% ±16.1) during bucketball compared to soccer (3 vs. 3 and 6 vs. 6, respectively). Players also travelled more distance at 13-17.9

$km \cdot hr^{-1}$ during 6 vs. 6 bucketball compared to soccer. The capacity of young athletes to perform high-intensity actions during SSGs may be dependent on their ability to execute the various technical executions the game requires. Therefore, the higher running speeds reported in bucketball may have been the result of sufficient technical ability to control the ball for long periods of time. Overall, players covered more distance at higher speeds and worked at more intense physiological workloads during bucketball compared to soccer and therefore a non sport-specific SSG could be considered a useful training tool for coaches of young athletes in a wide range of team sports.

8.1.1.3 Team selection strategy and playing regime

To further refine the prescription effectiveness of non sport-specific SSGs for young players, research investigating the optimal loading parameters was required (Hill-Haas, Rowsell, et al., 2009). Specifically, identifying the optimal playing regime is important from an adherence and effort perspective in younger populations. Furthermore, previous studies have allocated players into balanced SSG teams with respect to their combined physical skill and game intelligence ability to achieve high levels of intensity (physical and technical) (Hill-Haas et al., 2010; Hill-Haas, Dawson, et al., 2009). However, though logical, there is no evidence to indicate that this team selection strategy is in fact optimal for young athletes. Chapter 5 examined the effects of balanced and unbalanced team selection strategy and continuous and intermittent playing regimes on physical responses and technical skill outputs during 3 vs. 3 bucketball SSGs. Percent HR_{peak} (88.2 ± 1.2 vs. 86.8 ± 1.7) and time spent above 90% HR_{peak} (546 ± 116 s vs. 446 ± 158 s) was higher for balanced compared to unbalanced games. This finding confirms the importance of even team selection for eliciting high exercise intensity during SSGs in young players. Empirically, it is common for young athletes to decrease their playing intensity when they are dominating play or struggling to compete. Exercise intensity during continuous SSGs (16 min) exceeded 4 x 4 min SSGs interspersed with 90 s passive recovery (ES = 1.82) and 8 x 2 min SSGs interspersed with 45 s passive recovery (ES = 2.38). Similar results have been reported in adolescent (16.2 ± 0.2 years) soccer players (Hill-Haas, Rowsell, et al., 2009). The addition of passive rest between intermittent work bouts most likely allowed players time to recover and begin subsequent bouts with lower heart rates (Hill-Haas, Rowsell, et al., 2009). A moderate difference in RPE was reported between 16 min and 8 x 2 min games (effect size = 0.63), corresponding to the very large difference in exercise intensity. Therefore, RPE appears to be an adequate indicator of exercise intensity in young athletes during SSGs of distinctly different work:rest ratios.

Distance travelled above 18 $km \cdot hr^{-1}$ during balanced SSGs moderately exceeded unbalanced games (ES = 0.57). Higher running speeds have been associated with 'decisive actions' (times during a match when the game outcome is typically decided) during team sport (Dupont et al., 2004), which may have occurred more frequently during balanced SSGs as a result of more competitive playing environments. Team selection strategy and playing regime had no substantial effect on technical executions. Therefore, continuous SSGs balanced for team player allocation provided greater physiological load than unbalanced and intermittent games and therefore offer a superior training stimulus for potentially improving aerobic fitness. Alternatively, intermittent games balanced for team player allocation may offer an effective stimulus for training the associated demands of higher speed running, together with providing an appropriate stimulus for extensive aerobic fitness adaptation. Finally, balanced and unbalanced team selection, and continuous and intermittent SSGs, can be interchanged without affecting the quantity and quality of technical executions performed.

8.1.1.4 Rule modification and inter-game conditioning exercise

The modification of various SSG playing rules in practice is common, yet literature on the resultant effects on game outputs in young players is limited (Gabbett et al., 2010; Hill-Haas et al., 2010; Ngo et al., 2012). Furthermore, the inclusion of more traditional conditioning exercises during SSGs, such as high-speed shuttle running, is commonly used by coaches to superimpose additional physical work on their players without a good understanding of the ensuing effects (Hill-Haas et al., 2010). Therefore, chapter 6 examined the effect of two rule changes, and the inclusion of inter-game high-intensity running bouts, on the physiological and perceptual responses, time-motion characteristics and technical skill executions during a non sport-specific SSG in young athletes. With regard to rule modification, internal (physiological) loads experienced by players were substantially higher (ES = 0.55-0.73) during the non-modified SSG, which was in contrast to previous research investigating adolescent soccer players (Hill-Haas et al., 2010; Ngo et al., 2012; Sampaio et al., 2007). This suggests that similar rule modifications may not affect exercise intensity similarly for different types of SSGs and age groups. However, this format was associated with a reduction in the quality of technical executions performed. Alternatively, restriction of time in possession to 3 s led to more technical skill executions performed with higher quality (effect sizes = 0.62-1.67). Man-on-man marking maximised neither internal or external loads, nor the quantity or quality of technical executions and therefore this rule change should be prioritised for the tactical elements it may bring to SSG training in young athletes.

With the addition of inter-game conditioning exercise, external (movement) load substantially increased (8-13%) compared to all other SSG formats, which is in agreement with similar previous research (Hill-Haas et al., 2010) and presumably relates to the increase in distance travelled at speeds $\geq$18 km·hr^{-1} during this format (624 ± 137 m, 64.5 ± 55.1 m, 45.5 ± 27.7 m, and 63.3 ± 28.3 m for BB^{HR}, BB, BB^{3S} and BB^{MM}, respectively). However, the addition of inter-game high-intensity running blocks substantially decreased exercise intensity and the number of technical executions completed in subsequent SSGs play, which is an important consideration for exercise prescription. Finally, non-modified bucketball was perceived to be harder than playing formats with rule modifications, but lower than games including inter-game conditioning exercise. We concluded that the perceptual response of players was influenced by external load of the various SSG formats more so than internal load.

8.1.2 Training for Aerobic Fitness - SSGs versus high-intensity interval training

To inform training prescription for young team sport athletes, the long term effects of non sport-specific SSG training (i.e. bucketball) and HIIT on physical performance parameters were investigated in Chapter 7. Our study protocol involved comparing two sessions of SSGs training a week, for six weeks, to one SSG training and one HIIT a week for the same time period. Similar studies have been completed using sport-specific SSGs in soccer (Hill-Haas, Coutts, et al., 2009; Impellizzeri et al., 2006) and handball (Buchheit, Laursen, et al., 2009) players. The mean training effects on VO_{2peak} (1.6 to 5.5%), V_{IFT} (2.2 to 5.8%), vertical jump (1.4 to 4.7%) and sprint times (-1.1 to -5.1%) ranged from unclear to large. With the exception of the 5 and 20 m sprint, greater changes were seen following combined SSG and HIIT group, compared with SSGs training alone. Higher internal and external loads experienced by players during combined training accounted for the differences observed in performance. Based on athlete measures of heart rate, body load and perceived exertions during the different training regimes, it was concluded that the external load may be a key determining factor of perceived load at high exercise intensities in young athletes.

8.2 Limitations

The development of young athletes is a complex, dynamic progress that should account for many individual physical, social, mental and environmental factors. We acknowledge that most of the research undertaken in this thesis was cross-sectional rather than longitudinal in nature, which fails to recognise or acknowledge the interplay of the athlete's multitude of developmental components and the relative importance of aerobic fitness over time. However, given that examining the same population over an extended period of time poses many difficulties and that most studies investigating aerobic fitness development adopt cross-sectional methodology, this approach was adopted. Furthermore, any benefits associated with aerobic fitness training for young athletes reported in our findings should be interpreted in the context of the level of participation of the athletes who volunteered for our investigations, and therefore generalisation of findings to wider populations should be performed with caution. Information on the training history and ethnic characteristics of the participating athletes would be beneficial in future studies.

The methodological procedures in this thesis were primarily concerned with the assessment and development of $\dot{V}O_{2peak}$; only one component, albeit the gold standard, measure, of aerobic fitness. Analysis of other components of aerobic performance, such as lactate threshold and running economy, may have resulted in very different findings. Furthermore, aerobic performance in other physical tests (e.g. YYIRT1) can improve despite $\dot{V}O_{2peak}$ not substantially changing (Hill-Haas, Coutts, et al., 2009) or changing to a lesser degree. Therefore, investigation of other potential contributors to performance during commonly used aerobic field tests is required.

Other methodological procedures implemented in this thesis included GPS technology to measure body load, which provided a measure of total stress resulting from accelerations, decelerations, and changes of direction. Unfortunately, due to budget constraints, use of accelerometers, and therefore body load measurements, were restricted to Chapters 6 and 7. Use of accelerometers throughout this thesis would have added value to the findings. While interesting outcomes were reported, the literature assessing accelerometers in SSGs and HIIT training in young athletes is very limited, and therefore further investigations are required to develop a greater understanding of how tri-axis accelerometer data can be used to assist with training programme development.

In an attempt to optimise physical and technical development in young team sport athletes, this thesis specifically investigated the non sport-specific SSG bucketball. It is possible that similar results may be observed using other non sport-specific SSGs in which the technical aspects allow for high-intensity exercise by maintaining game flow and limiting breaks in play. It may be considered that effective SSGs for developing aerobic fitness in young athletes are those that are physically demanding yet allow players to maximize and refine fundamental technical and tactical skills and decision-making abilities. Nonetheless, the findings from this thesis should assist athletes and coaches involved with the development of aerobic fitness in young team sport athletes to better understand the use of SSGs.

8.3 Practical applications

The overall aim of this thesis was to investigate the optimisation of aerobic fitness development in young (<14 years) male team sport athletes in New Zealand. To this end, we chose to examine a ‘novel’ non sport-specific SSG (bucketball) through a series of investigations structured progressively. Based on our findings, a summary of practical applications to assist coaches and sport scientists working with team sports to understand how to manipulate SSG variables to achieve a desired physical or technical adaptation is presented in Figure 8.1.

We recommend that coaches of young (<14 years) team sport players consider the addition of a non sport-specific SSG to their training regime. Given that a generic catch and pass game incorporates fundamental skills, it may be considered as a useful training tool by coaches in a wide range of team sports. For players involved in sports in which possession is controlled with the hands, it will not only provide an opportunity to improve physical characteristics but also develop technical game skills (including passing, catching and shooting) at the same time. However, importantly, it may also provide benefits to young players involved in sports where game intensity is reliant on a reasonably high level of skill to maintain control of the ball (e.g. soccer, hockey).

To optimise the development of aerobic fitness in young team sport athletes, we recommend the prescription of combined SSGs and individualised HIIT regimes. For the specific purpose of increasing aerobic fitness with SSGs, we recommend the use of a non sport-specific, 3 vs. 3 continuous format for which balanced teams have been allocated and no adjustment to the rules have been made. Alternatively, playing formats should be adjusted when other adaptations are desired. Specifically, the manipulation of game rules (i.e. 3 s possession) can lead to an increase in the quality and quantity of technical skill executions, while different work:rest ratios (i.e. intermittent) can result in more time spent travelling at higher speeds. Intermittent regimes also provide the opportunity for direct coach input during the passive recovery periods that may lead to better skill acquisition in young athletes. To increase both internal and external loads of players, inter-game high-intensity interval running bouts should be prescribed, but exercise intensity and the number of technical skills players execute in subsequent game play will likely reduce. Implementation of RPE with young team sport players during SSGs should be done with care. More work is needed to investigate the use of RPE with young athletes involving substantial familiarisation and habituation. In addition, external training load may be more of a determining factor in perceived exertion than internal load. Accordingly, RPE that differentiates between internal and external load (e.g. difficulty of breathing vs. soreness of legs) may be worthwhile. In all cases, prescription of variables associated with a non sport-specific SSG training should be based on the training history, level of participation and specific training adaptation desired for the athletes involved.

While the use of a non sport-specific SSG is beneficial to develop physical attributes and generic technical skills, the acquisition and application of sport-specific skill, when access to young athletes is often limited (i.e. 1-2 times per week), is an important consideration to optimise player development. However, transferability of non-specific tactical tasks in games exists across many invasion games. Consequently, coaches could take advantage of the physiological benefits that non sport-specific SSGs provide, while at the same time develop tactical capabilities in their players specific to the sport they are coaching. In addition, exposure of athletes in their formative years to increased structured and deliberate invasion game play has been shown to improve the acquisition of perceptual and decision making skills.

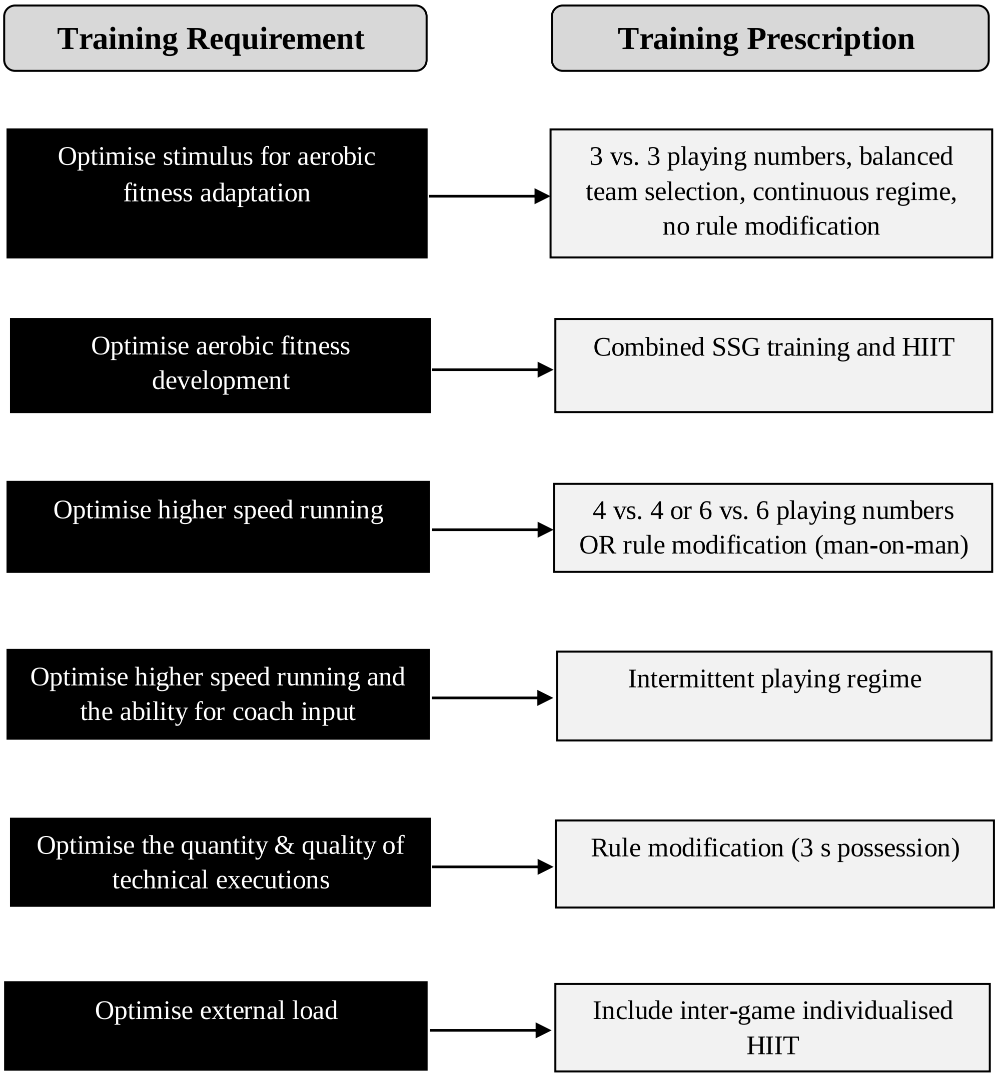


Figure 8.1 - Practical applications of non sport-specific SSG training.

SSG, small-sided game; HIIT, high-intensity interval training.

8.4 Future Research

This thesis concentrated on one SSG specifically (i.e. bucketball). Future studies elucidating other effective SSGs for developing aerobic fitness in young team sport athletes (<14 years) would be worthwhile. Importantly, these studies should include methodologies to investigate physiological and technical outputs concurrently, considering the importance of skill acquisition for athletes during the sampling and specialisation stages of development. Moreover, future research should investigate both sport-specific and non sport-specific SSGs for practical applications to young athletes participating in a mix of different team sports. In addition, this thesis highlighted some interesting findings concerning body load and perceived exertion during SSGs and HIIT. As literature assessing the use of accelerometers in young athletes is limited, further investigations are required to develop a greater understanding of how these devices can be used effectively. Furthermore, future work investigating the use of metabolic power estimations may be beneficial to advance our understanding of the demands of SSGs training (Osgnach, Poser, Bernardini, & Rinaldo, 2010).

The role of a central cardiovascular measure (i.e. $\dot{V}O_{2peak}$) in the development of aerobic fitness was the focus in this thesis. Future investigations are required to explore other parameters, including lactate threshold and running/movement economy, which may contribute to the natural development and trainability of aerobic fitness in young athletes. Furthermore, elucidation of the other physiological mechanisms contributing to the development of aerobic fitness, such as enzymatic and hormonal changes, would increase the current understanding in this area. Given that athlete development is a dynamic and longitudinal process, the change in aerobic fitness and its components over several years would provide additional information to the findings reported in the current thesis.

Longitudinal research design would help to delineate any combined effects of maturation and training on the development of aerobic fitness in team sport players.

Finally, future research should build on the findings reported in Chapter 7 of this thesis, by investigating different methods of training for developing aerobic fitness in young team sport athletes. Studies should examine different training methods within the same maturity group to help guide the implementation of best practice for developing aerobic fitness. Alternatively, studies could investigate the same training protocol across different maturity groups to provide valuable information on the dose-response relationship of aerobic fitness development in young athletes.

8.5 Conclusion

This thesis demonstrated, for the first time, the effect of manipulating the design of a non sport-specific SSG on the physiological, movement and technical characteristics and performance variables in players aged 12 to 14 years. Our results showed that a 3 vs. 3 continuous SSG, balanced for team selection and with rule no modifications, elicited the highest exercise intensity and therefore its use is recommended for aerobic fitness training with young players. Furthermore, players covered more distance at higher speeds and worked at more intense physiological workloads during bucketball compared to soccer and therefore a non sport-specific SSG could be considered as a useful training tool for coaches of young athletes in a wide range of team sports. Alternatively, intermittent games balanced for team player allocation may offer an effective stimulus for training the associated demands of higher speed running, together with providing an appropriate stimulus for extensive aerobic fitness adaptation. Lastly, a combination of SSGs training and traditional high-intensity interval training was more effective at increasing aerobic fitness in young team sport players than SSGs training alone and therefore is recommended to optimise the development of aerobic fitness in young team sport players.

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Appendices

Appendix 1: Ethical approval

AUT UNIVERSITY
TE WĀNANGA ARONUI O TAMAKI MAKAU RAU

MEMORANDUM

Auckland University of Technology Ethics Committee (AUTEC)

To:	Andrew Kilding
From:	**Dr Rosemary Godbold** Executive Secretary, AUTEC
Date:	13 December 2011
Subject:	Ethics Application Number 11/98 **Optimisation of aerobic fitness development in young athletes.**

Dear Andrew

Thank you for providing written evidence as requested. I am pleased to advise that it satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC) at their meeting on 9 May 2011 and I have approved your ethics application. This delegated approval is made in accordance with section 5.3.2.3 of AUTEC's *Applying for Ethics Approval: Guidelines and Procedures* and is subject to endorsement at AUTEC's meeting on 23 January 2012.

Your ethics application is approved for a period of three years until 13 December 2014.

I advise that as part of the ethics approval process, you are required to submit the following to AUTEC:

- A brief annual progress report using form EA2, which is available online through http://www.aut.ac.nz/research/research-ethics/ethics. When necessary this form may also be used to request an extension of the approval at least one month prior to its expiry on 13 December 2014;
- A brief report on the status of the project using form EA3, which is available online through http://www.aut.ac.nz/research/research-ethics/ethics. This report is to be submitted either when the approval expires on 13 December 2014 or on completion of the project, whichever comes sooner;

It is a condition of approval that AUTEC is notified of any adverse events or if the research does not commence. AUTEC approval needs to be sought for any alteration to the research, including any alteration of or addition to any documents that are provided to participants. You are reminded that, as applicant, you are responsible for ensuring that research undertaken under this approval occurs within the parameters outlined in the approved application.

Please note that AUTEC grants ethical approval only. If you require management approval from an institution or organisation for your research, then you will need to make the arrangements necessary to obtain this.

When communicating with us about this application, we ask that you use the application number and study title to enable us to provide you with prompt service. Should you have any further enquiries regarding this matter, you are welcome to contact me by email at ethics@aut.ac.nz or by telephone on 921 9999 at extension 6902.

On behalf of AUTEC and myself, I wish you success with your research and look forward to reading about it in your reports.

Yours sincerely

Dr Rosemary Godbold
Executive Secretary
Auckland University of Technology Ethics Committee

Cc: Craig Harrison craig.harrison@vodafone.co.nz

Appendix 2. Participant information sheets

Participant Information Sheet

Quantification of physiological, movement and skill demands during two different small-sided games in young athletes

9 May 2011

Hi, my name is Craig Harrison and I am doing some research at AUT University. I'd like to invite you to help me with my project investigating the best fitness training for young team sport athletes like yourselves.

Please read this information and decide whether or not you would like to be involved in my project. You don't have to be involved, and you can stop being involved in the project at any time without any negative effects for yourself.

What is the project for?

It is important for team sport players to be fit to help them perform better during games. When we think of the best way to get fitter we think of lots of running, but a better and more fun way to do it could be to play small-sided games. We know that small-sided games are good for adults but we don't know how good they are at getting young players fit, so I'd like to do some research to find out.

What will happen in the project?

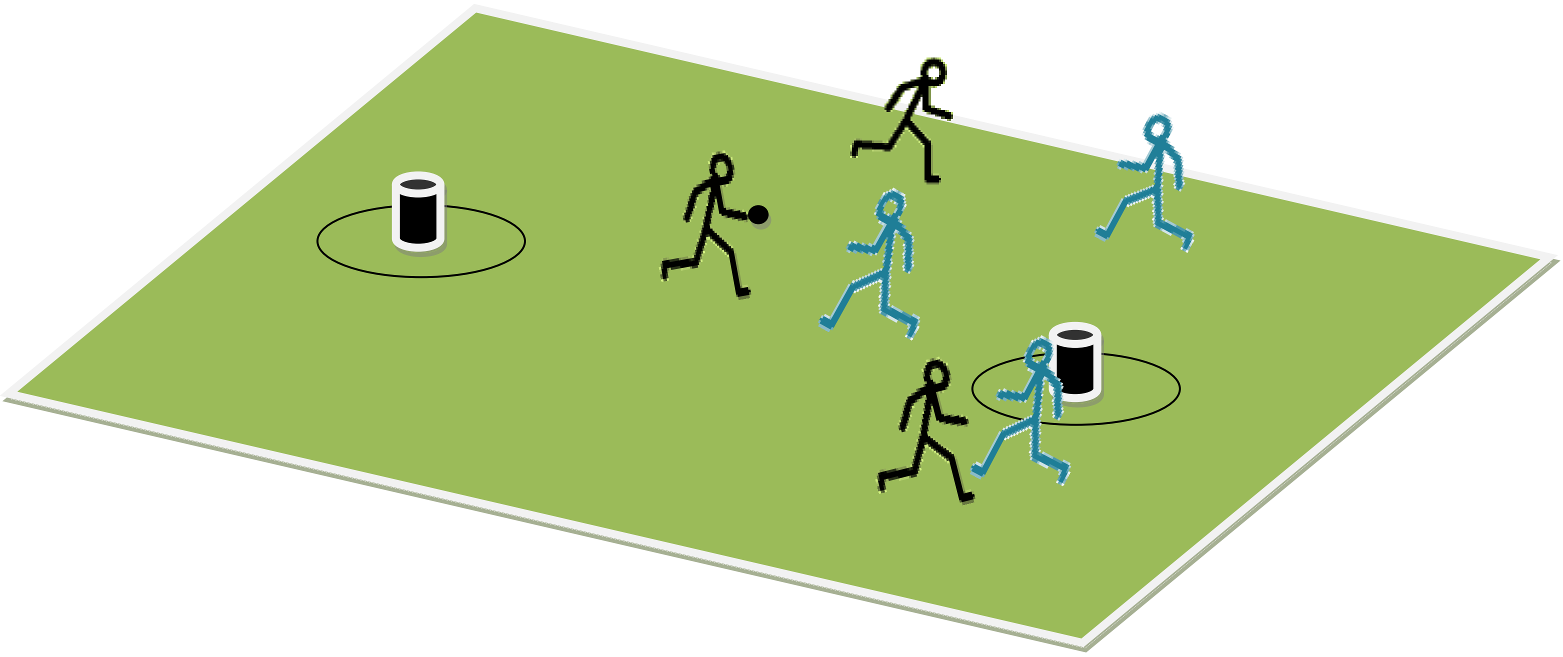
In the first two weeks you will do a fitness test and be taught how to play some small-sided games. Then over the next three weeks you will play six different small-sided games two times each.

1. *Treadmill fitness test*

   After a practice running on the treadmill you will do a test to see how fit you are. The test starts at a slow speed then gradually gets faster until you get tired and have to stop. While running you will be wearing a mouthpiece which is like wearing a swimming snorkel and a heart rate monitor around your chest. You will be encouraged to push yourself as hard as you can go.

2. *Small-sided games*

   You will play games of Soccer and a new game called Bucketball where you have to pass a ball around to score a goal in the other teams bucket. On separate days, you will play games of Soccer and Bucketball with three, four and six players on each team that last for 16 minutes each. During the games you will wear a small monitor (cell phone size) to measure your heart rate and how far you run, and at the end of each game you be asked how hard you think you worked from a chart given to you. All the games will also be video recorded to see how well you performed skills during the game.



Above: 3 vs. 3 game of Bucketball

Important notes about the project

1. You will get to know all about your fitness level in a report and learn about the best training for you to get better
2. You will get to know about popular fitness games that top sports teams are currently using
3. You may feel tired or get sore muscles after doing these test but it won't be any worse than a hard training
4. There will be lots of safety people close by in case of an emergency
5. Your fitness test results will be kept private
6. You can pull out of the project at any time
7. Take your time to decide if you would like to do the project. If you decide to do it please fill in the accent form and return in back to me.

Thank you for taking the time to read this information.

What do I do if I have concerns about this research? Added section

Please get one of your parents or caregiver to contact the Project Supervisor:

Assoc. Prof. Andrew Kilding, Institute of Sport & Recreation Research New Zealand, School of Sport and Recreation, AUT University, Private Bag 92006, Auckland 1020, Ph 921 9999 ext. 7076, Andrew.kilding@aut.ac.nz

Concerns regarding the conduct of the research should be notified to the Executive Secretary, AUTEC, Madeline Banda, madeline.banda@aut.ac.nz, Ph 921 9999 ext 8044.

Whom do I contact for further information about this research?

Researcher Contact Details:

Craig Harrison, School of Sport and Recreation, AUT University / Millennium LTAD Coordinator ltad@mish.org.nz Ph 477 2012

Project Supervisor Contact Details:

Assoc. Prof. Andrew Kilding, Institute of Sport & Recreation Research New Zealand, School of Sport and Recreation, AUT University, Private Bag 92006, Auckland 1020, Ph 921 9999 ext. 7056, Andrew.kilding@aut.ac.nz

Approved by the Auckland University of Technology Ethics Committee on 09/05/2011. AUTEC Reference number 11/98

Participant Information Sheet

Physiological, movement and skill demands of a generic catch and pass small-sided game in young athletes: effect of changing game duration and team player assignment

9 May 2011

Hi, my name is Craig Harrison and I am doing some research at AUT University. I'd like to invite you to help me with my project investigating the best fitness training for young team sport athletes like yourselves.

Please read this information and decide whether or not you would like to be involved in my project. You don't have to be involved, and you can stop being involved in the project at any time without any negative effects for yourself.

What is the project for?

It is important for team sport players to be fit to help them perform better during games. When we think of the best way to get fitter we think of lots of running, but a better and more fun way to do it could be to play small-sided games. We know that small-sided games are good for adults but we don't know how good they are at getting young players fit, so I'd like to do some research to find out.

What will happen in the project?

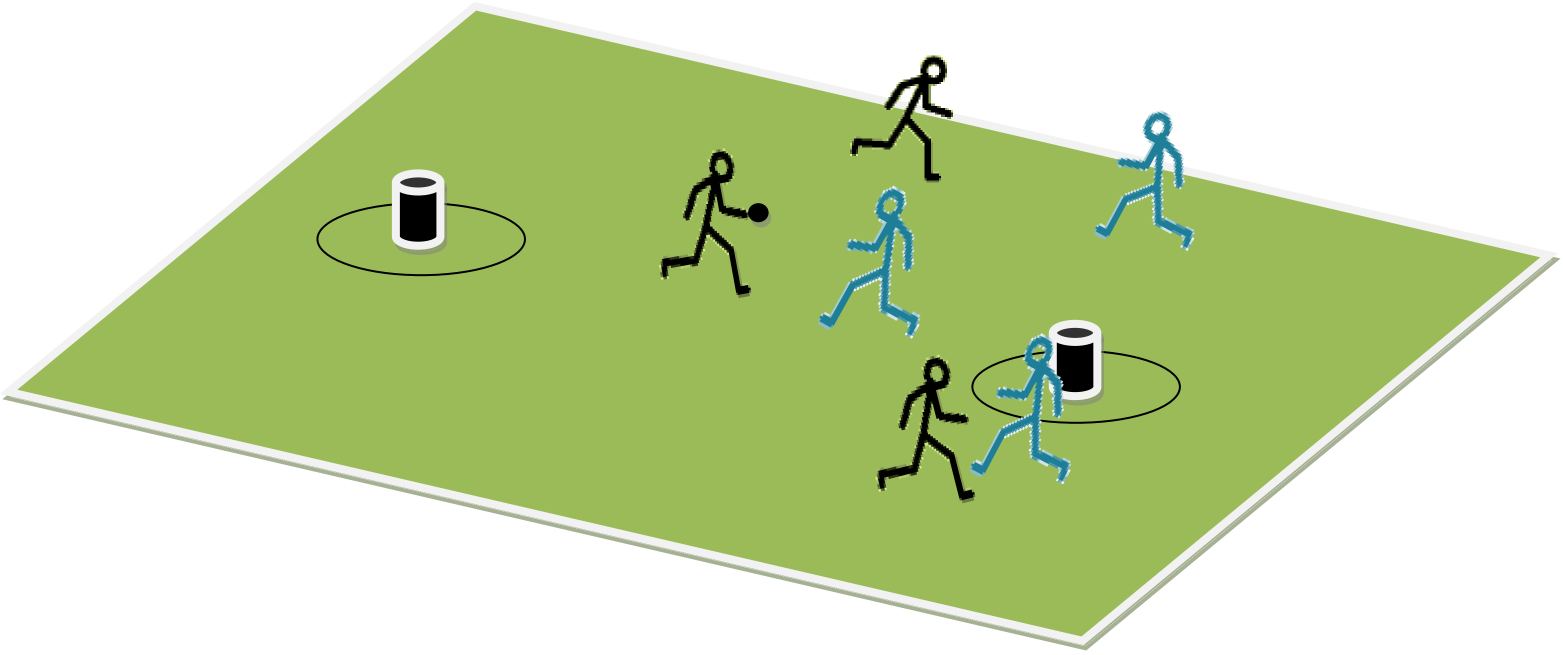
In the first week you will be taught how to play some small-sided games. Then over the next three weeks you will play a variety small-sided games two times each AND complete a fitness test at the Millennium Institute of Sport.

3. *Treadmill fitness test*

   After a practice running on the treadmill you will do a test to see how fit you are. The test starts at a slow speed then gradually gets faster until you get tired and have to stop. While running you will be wearing a mouthpiece which is like wearing a swimming snorkel and a heart rate monitor around your chest. You will be encouraged to push yourself as hard as you can go.

4. *Small-sided games*

   You will play a new game called Bucketball where you have to pass a ball around to score a goal in the other team's bucket. You will play 12 games made different by the number of player on your team or how long the game lasts for. During the games you will wear a small monitor (cell phone size) to measure your heart rate and how far you run, and at the end of each game you be asked how hard you think you worked from a chart given to you. All the games will also be video recorded to see how well you performed skills during the game.



Above: 3 vs. 3 game of Bucketball

Important notes about the project

8. You will get to know all about your fitness level in a report and learn about the best training for you to get better
9. You will get to know about popular fitness games that top sports teams are currently using
10. You may feel tired or get sore muscles after doing these test but it won't be any worse than a hard training
11. There will be lots of safety people close by in case of an emergency
12. Your fitness test results will be kept private
13. You can pull out of the project at any time
14. Take your time to decide if you would like to do the project. If you decide to do it please fill in the accent form and return in back to me.

Thank you for taking the time to read this information.

What do I do if I have concerns about this research? Added section

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Assoc. Prof. Andrew Kilding, Institute of Sport & Recreation Research New Zealand, School of Sport and Recreation, AUT University, Private Bag 92006, Auckland 1020, Ph 921 9999 ext. 7076, Andrew.kilding@aut.ac.nz

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Researcher Contact Details:

Craig Harrison, School of Sport and Recreation, AUT University / Millennium LTAD Coordinator ltad@mish.org.nz Ph 477 2012

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Approved by the Auckland University of Technology Ethics Committee on 09/05/2011. AUTEC Reference number 11/98

Participant Information Sheet

AUT UNIVERSITY
TE WĀNANGA ARONUI O TAMAKI MAKAU RAU

Effect of rule changes and conditioning blocks on the physiological, movement and skill demands of a generic catch and pass small-sided games in young athletes

9 May 2011

Hi, my name is Craig Harrison and I am doing some research at AUT University. I'd like to invite you to help me with my project investigating the best fitness training for young team sport athletes like yourselves.

Please read this information and decide whether or not you would like to be involved in my project. You don't have to be involved, and you can stop being involved in the project at any time without any negative effects for yourself.

What is the project for?

It is important for team sport players to be fit to help them perform better during games. When we think of the best way to get fitter we think of lots of running, but a better and more fun way to do it could be to play small-sided games. We know that small-sided games are good for adults but we don't know how good they are at getting young players fit, so I'd like to do some research to find out.

What will happen in the project?

In the first two weeks you will do two different fitness tests and be taught how to play the small-sided games. Then over the next three weeks you will play eight different small-sided games two times each.

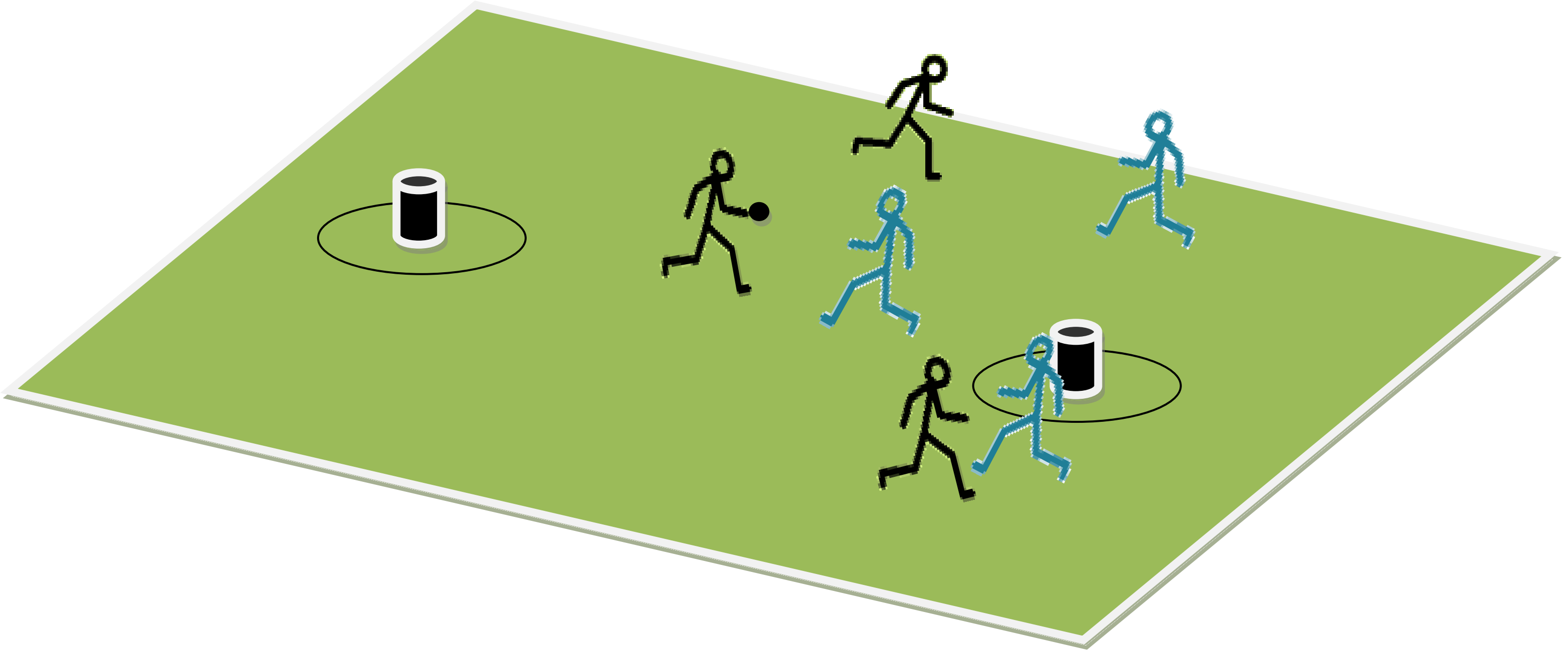
1. *Fitness tests*

   Treadmill running test - After a practice running on the treadmill you will do a test to see how fit you are. The test starts at a slow speed then gradually gets faster until you get tired and have to stop. While running you will be wearing a mouthpiece which is like wearing a swimming snorkel and a heart rate monitor around your chest. You will be encouraged to push yourself as hard as you can go.

   30-15 Intermittent Fitness Test – This test is like the beep test that you may have done before. After a good warm the test involves running back and forth with a 15 second rest every 30 seconds. The test gets faster and faster until you have to stop. You will be encouraged to push yourself as hard as you can and reach the highest score possible. You will be asked how hard you think you worked after each test from a chart given to you.

2. *Small-sided games*

   You will play variations of a new game called Bucketball where you have pass a ball around to score a goal in the other teams bucket. Some of the games will have changes to the rules and during other games you will stop playing and complete some short, fast interval running and then return to the game. During the games you will wear a small monitor (cell phone size) to measure your heart rate and how far you run, and at the end of each game you be asked how hard you think you worked from a chart given to you. All the games will also be video recorded to see how well you performed skills during the game.



Above: 3 vs. 3 game of Bucketball

Important notes about the project

1. You will get to know all about your fitness level in a report and learn about the best training for you to get better
2. You will get to know about popular fitness games that top sports teams are currently using
3. You may feel tired or get sore muscles after doing these test but it won't be any worse than a hard training
4. There will be lots of safety people close by in case of an emergency
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Whom do I contact for further information about this research?

Researcher Contact Details:

Craig Harrison, School of Sport and Recreation, AUT University / Millennium LTAD Coordinator ltad@mish.org.nz Ph 477 2012

Project Supervisor Contact Details:

Assoc. Prof. Andrew Kilding, Institute of Sport & Recreation Research New Zealand, School of Sport and Recreation, AUT University, Private Bag 92006, Auckland 1020, Ph 921 9999 ext. 7056, Andrew.kilding@aut.ac.nz

Approved by the Auckland University of Technology Ethics Committee on 09/05/2011. AUTEC Reference number 11/98

Participant Information Sheet

AUT UNIVERSITY
TE WĀNANGA ARONUI O TAMAKI MAKAU RAU

Efficacy of small-sided games to enhance aerobic fitness in young athletes

9 May 2011

Hi, my name is Craig Harrison and I am doing some research at AUT University. I'd like to invite you to help me with my project investigating the best fitness training for young team sport athletes like yourselves.

Please read this information and decide whether or not you would like to be involved in my project. You don't have to be involved, and you can stop being involved in the project at any time without any negative effects for yourself.

What is the project for?

It is important for team sport players to be fit to help them perform better during games. When we think of the best way to get fitter we think of lots of running, but a better and more fun way to do it could be to play small-sided games. We know that small-sided games are good for adults but we don't know how good they are at getting young players fit, so I'd like to do some research to find out.

What will happen in the project?

In the first week you will do four different fitness tests and be taught how to play the small-sided games. Then over the next six weeks you will either play a small-sided game twice a week on separate days, or complete a combination of small-sided games and high-intensity, intermittent running training twice a week on separate days. At the end of the six weeks of training you will do the same four fitness tests you did at the start again to see if you are fitter.

1. *Fitness tests*

Treadmill running test - After a practice running on the treadmill you will do a test to see how fit you are. The test starts at a slow speed then gradually gets faster until you get tired and have to stop. While running you will be wearing a mouthpiece which is like wearing a swimming snorkel and a heart rate monitor around your chest. You will be encouraged to push yourself as hard as you can go.

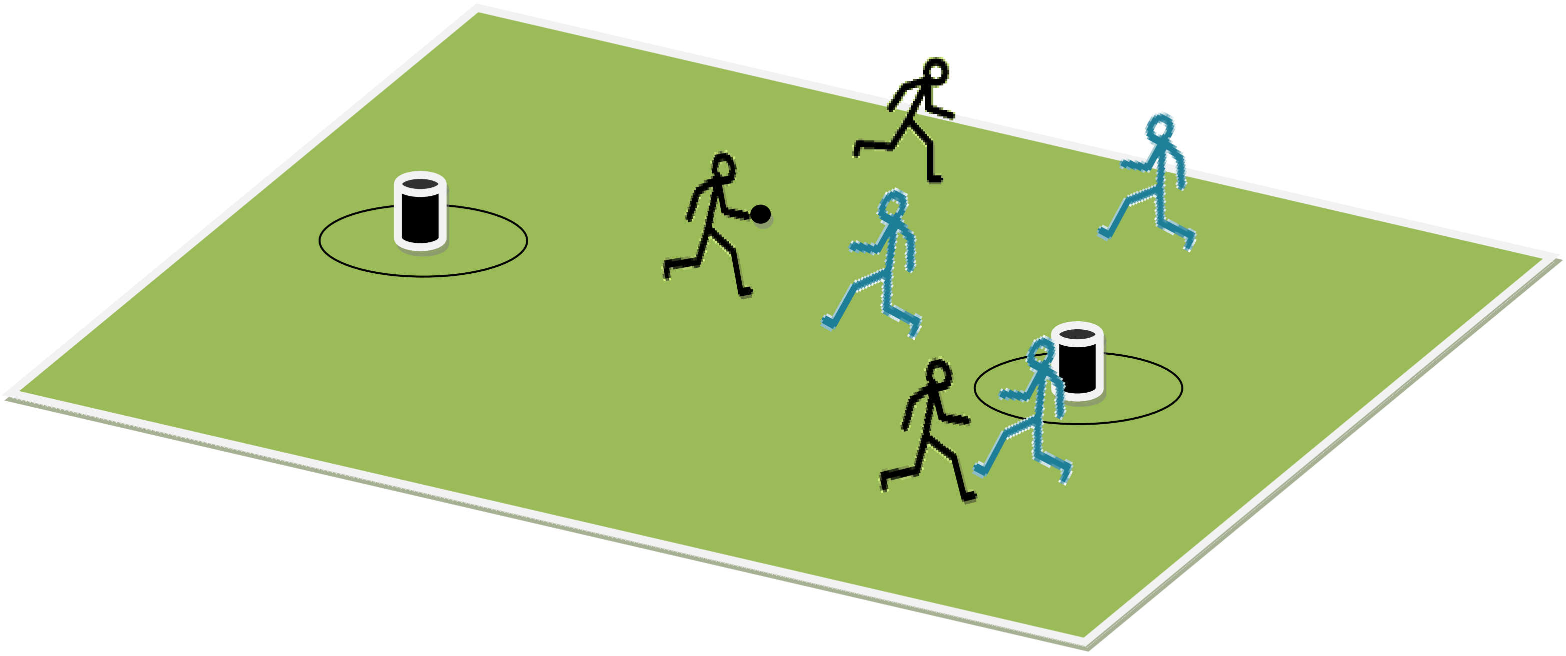
30-15 Intermittent Fitness Test – This test is like the beep test that you may have done before. After a good warm the test involves running back and forth with a 15 second rest every 30 seconds. The test gets faster and faster until you have to stop. You will be encouraged to push yourself as hard as you can and reach the highest score possible. You will be asked how hard you think you worked after each test from a chart given to you.

Jump test – You will jump as high as you can on a force platform that will measure how high you get

Speed test - You will run as fast as you can for 30 meters between two sets of timing gates that will record your speed

2. *Small-sided games*

You will play a new game called Bucketball where you have pass a ball around to score a goal in the other teams bucket. During the games you will wear a GPS to measure your heart rate and how far you run, and at the end of each game you be asked how hard you think you worked from a chart given to you. All the games will also be video recorded to see how well you performed skills during the game.



Above: 3 vs. 3 game of Bucketball

3. *High-intensity, intermittent running training*

You will perform high-intensity, intermittent running consisting of 15 seconds of running followed by 15 seconds of rest for the same amount of time as the small-sided games training.

Important notes about the project

1. You will get to know all about your fitness level in a report and learn about the best training for you to get better
2. You will get to know about popular fitness games that top sports teams are currently using
3. You may feel tired or get sore muscles after doing these test but it won't be any worse than a hard training
4. There will be lots of safety people close by in case of an emergency
5. Your fitness test results will be kept private
6. You can pull out of the project at any time
7. Take your time to decide if you would like to do the project. If you decide to do it please fill in the accent form and return in back to me.

Thank you for taking the time to read this information.

What do I do if I have concerns about this research?

Please get one of your parents or caregiver to contact the Project Supervisor:

Assoc. Prof. Andrew Kilding, Institute of Sport & Recreation Research New Zealand, School of Sport and Recreation, AUT University, Private Bag 92006, Auckland 1020, Ph 921 9999 ext. 7076, Andrew.kilding@aut.ac.nz

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Whom do I contact for further information about this research?

Researcher Contact Details:

Craig Harrison, School of Sport and Recreation, AUT University / Millennium Athlete Development Academy Director charrison@mish.org.nz Ph 477 2012

Project Supervisor Contact Details:

Assoc. Prof. Andrew Kilding, Institute of Sport & Recreation Research New Zealand, School of Sport and Recreation, AUT University, Private Bag 92006, Auckland 1020, Ph 921 9999 ext. 7056, Andrew.kilding@aut.ac.nz

Approved by the Auckland University of Technology Ethics Committee on 09/05/2011. AUTEC Reference number 11/98

Appendix 3: Parent information sheets

Parent / Guardian Information Sheet

Date Information Sheet Produced:
9 May 2011

Project Title
Quantification of physiological, movement and skill demands during two different small-sided games in young athletes

An Invitation

Hi my name is Craig Harrison. I am a PHD student at AUT University. My supervisor Assoc. Prof. Andrew Kilding and I would like to invite your child to help with a project that is investigating the best aerobic fitness training for young team sport athletes.

Please read the following and decide whether or not you would like your child to be involved. They don't have to be involved, and you can stop their involvement in the study at any time without any adverse consequences.

What is the purpose of this research?

It is important for team sport players to be fit to help them perform at their best during games. Traditionally fitness training involves long slow continuous or short fast interval running. However a different way to achieve the same results while much more enjoyable for athletes could be to play well prescribed small-sided games. Small-sided games are adapted from the original form of a sport that involve a reduced number of players and are designed for a specific purpose. Studies have demonstrated that small-sided games are effective at developing aerobic fitness in adults but we don't know how good they are at doing the same for young players. Therefore the purpose of this research is to examine the effectiveness of small-sided games for aerobic fitness development in young athletes.

How was your child chosen for this invitation?

Your child plays in a team sport and is within a year either side of their peak height velocity (PHV). PHV is the time during your child's physical development when they will be growing their fastest. Your child trains at least two times per week and competes in intermittent sports at least once per week.

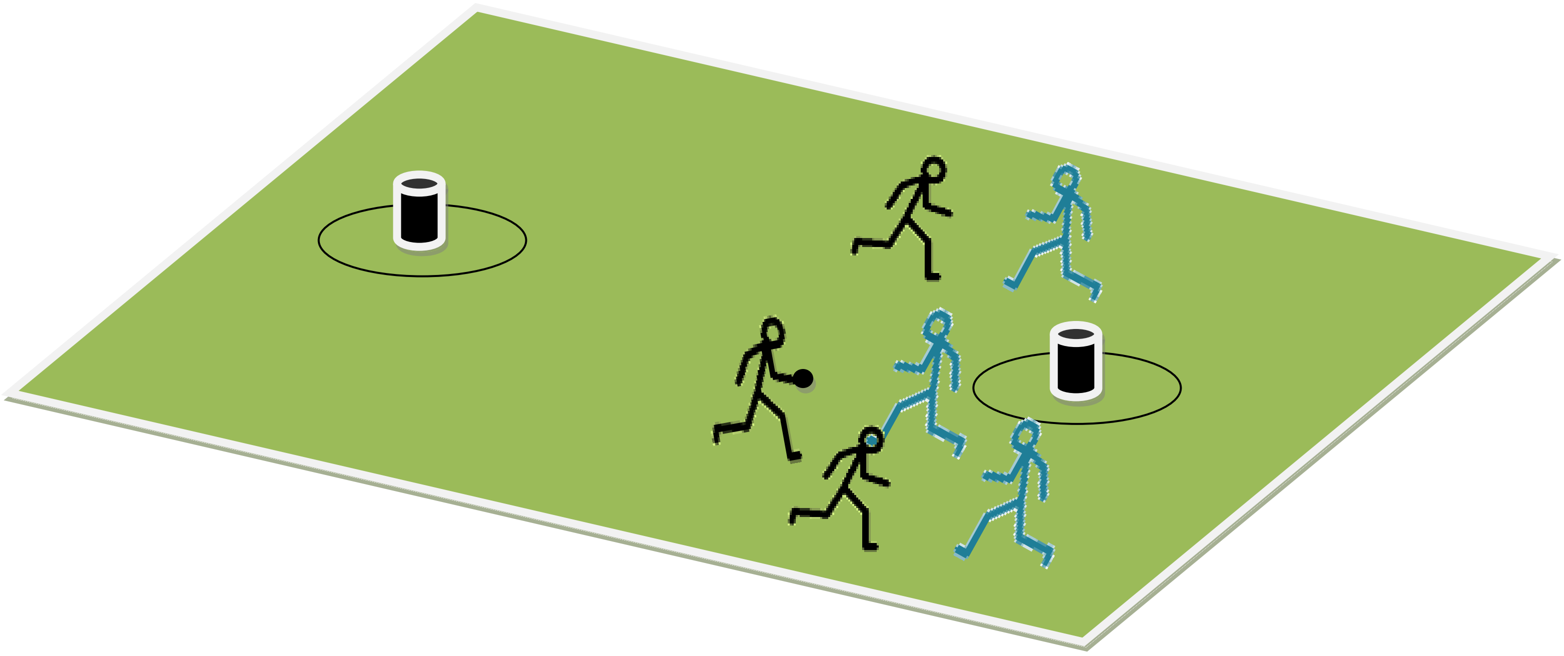
What will happen in this research?

If you choose for your child to participate in this study, they will be required to perform a fitness test and be taught some small-sided games in the first two weeks of the study. Then in the following three weeks they will be required to participate in a variety of small-sided games during which a number of physiological and fitness variables will be monitored.

- Treadmill test – Your child will first get to complete a familiarisation session to get use to the laboratory, the treadmill running, and wearing the gas analysis equipment (this involves wearing a mouthpiece which is like wearing a swimming snorkel and a heart rate monitor around the chest).

Your child will perform a maximal exercise test on the treadmill to accurately measure their fitness (VO_{2max}). The test starts at an easy pace and then increases gradually until you cannot keep up with the speed. Your child will be asked to push themselves as hard as they can.

- Small-sided games – Your child will play small-sided games of Soccer and a new game called Bucketball which involves passing a ball around to score a goal in the opposing team's bucket (see below). Your child will play these games with three, four and six players on each team that last for 16 minutes two times each. Your child will wear a GPS device to measure their heart rate and distance and speeds which they ran during the games. At the end of each game your child will be asked how hard they thought they worked from a chart given to them. All the games will also be video recorded to see how well your child performed skills during the game



Above: 3 vs. 3 game of Bucketball

Throughout the testing period your child will be asked to maintain their normal level of training but not do any very hard exercise the day before testing. Care will be taken to plan testing sessions around your child's training programme. The small-sided games will take place at the same time of the day during your child's normal training session. Your child will be asked to visit the Millennium of Sport and Health to complete their treadmill test at a time outside of these sessions. Finally, your child will be asked to wear the same footwear and similar clothing for each testing session.

What are the discomforts and risks?

Potential side effects may include:

- Fatigue and sore muscles - similar to those experienced after a hard training session or game.
- Dizziness and possible fainting from high levels of physical exertion - similar to those experienced after a hard training session or game.

How will these discomforts and risks be eased?

During the maximal fitness test there will be attendants present who will be able to assist your child if they are feeling unwell. Within the facility there are staff members who are qualified in first aid, and there is a defibrillator available in case of an emergency. A telephone will also be on hand to call for immediate assistance if needed.

What are the benefits?

Following the study you will receive the outcome of your child's results in a written report. Therefore you will learn a lot about your child's individual fitness and how they can improve their training in the future. Your child will experience some new fitness techniques that are becoming more and more popular within team sport training environments.

What compensation is available for injury or negligence?

In the unlikely event of a physical injury as a result of your child's participation in this study, rehabilitation and compensation for injury by accident may be available from the Accident Compensation Corporation, providing the incident details satisfy the requirements of the law and the Corporation's regulations.

How will your child's privacy be protected?

The information will remain in locked storage and will only be accessible to the researcher and the academic supervisors for this project. No-one will be able to identify your child from any of the summary findings for the report of the project as all information related to you will be coded. Information regarding your child's results will only be passed onto others with your permission.

What are the costs of participating in this research?

You will incur travel costs to LTAD as these will not be covered by the researcher. Your child will be required to undergo one test taking approximately 30 minutes and 12 games taking approximately 20 minutes each. Approximately half an hour will be required for a familiarisation session on the treadmill, and this will be done prior to the first test. This is to ensure the tests run smoothly. In this time you will also complete initial consent forms, and any queries you have will be answered verbally.

What opportunity do I have to consider this invitation?

- You may take the time you need and decide whether or not you would like your child to be involved
- You can stop your child's involvement in the project at any point.

How do I agree to my child participating in this research?

If you agree to your child participating you will need to fill out a consent form and have your child sign an accent form.

Will I receive feedback on the results of this research?

Yes, individual feedback will be provided to you. The group results will be used in a written report as part of my degree qualification (copy of report available upon request) and the study's findings may eventually be published in a scientific journal.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor:

Assoc. Prof. Andrew Kilding, Institute of Sport & Recreation Research New Zealand, School of Sport and Recreation, AUT University, Private Bag 92006, Auckland 1020, Ph 921 9999 ext. 7076, Andrew.kilding@aut.ac.nz

Concerns regarding the conduct of the research should be notified to the Executive Secretary, AUTEC, Madeline Banda, madeline.banda@aut.ac.nz, Ph 921 9999 ext 8044

Whom do I contact for further information about this research?

Researcher Contact Details:

Craig Harrison, School of Sport and Recreation, AUT University / Millennium LTAD Coordinator
ltad@mish.org.nz Ph 477 2012

Project Supervisor Contact Details:

Assoc. Prof. Andrew Kilding, Institute of Sport & Recreation Research New Zealand, School of Sport and Recreation, AUT University, Private Bag 92006, Auckland 1020, Ph 921 9999 ext. 7056,
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Approved by the Auckland University of Technology Ethics Committee on 09/05/2011

AUTEC Reference number 11/98

Parent / Guardian Information Sheet

Date Information Sheet Produced:
9 May 2011

Project Title
Physiological, movement and skill demands of a generic catch and pass small-sided game in young athletes: effect of changing game duration and team player assignment

An Invitation

Hi, my name is Craig Harrison. I am a PHD student at AUT University. My supervisor Assoc. Prof. Andrew Kilding and I would like to invite your child to help with a project that is investigating the best aerobic fitness training for young team sport athletes.

Please read the following and decide whether or not you would like your child to be involved. They don't have to be involved, and you can stop their involvement in the study at any time without any adverse consequences.

What is the purpose of this research?

It is important for team sport players to be fit to help them perform at their best during games. Traditionally fitness training involves long slow continuous or short fast interval running. However a different way to achieve the same results while much more enjoyable for athletes could be to play well prescribed small-sided games. Small-sided games are adapted from the original form of a sport that involve a reduced number of players and are designed for a specific purpose. Studies have demonstrated that small-sided games are effective at developing aerobic fitness in adults but we don't know how good they are at doing the same for young players. Therefore the purpose of this research is to examine the effectiveness of small-sided games for aerobic fitness development in young athletes.

How was your child chosen for this invitation?

Your child plays in a team sport and is within a year either side of their peak height velocity (PHV). PHV is the time during your child's physical development when they will be growing their fastest. Your child trains at least two times per week and competes in intermittent sports at least once per week.

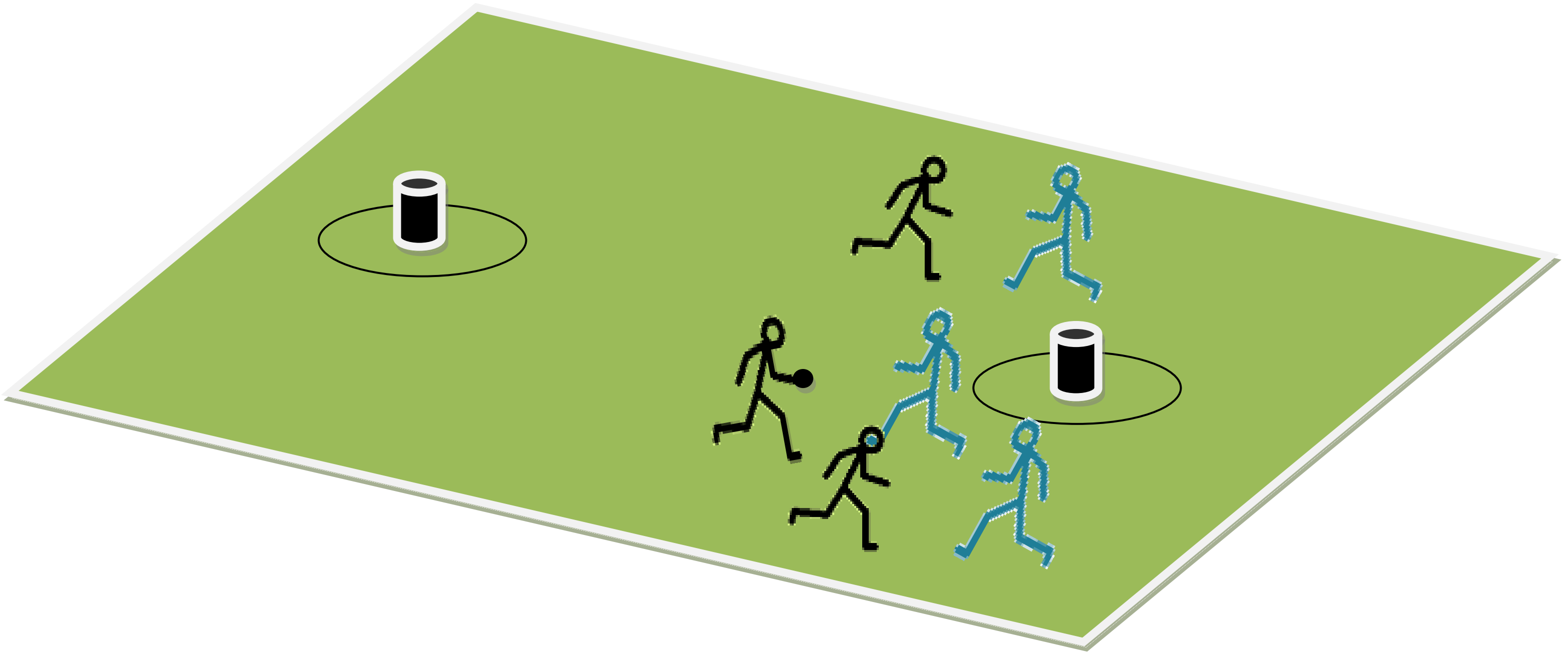
What will happen in this research?

If you choose for your child to participate in this study, they will be required to perform a fitness test and be taught some small-sided games in the first two weeks of the study. Then in the following three weeks they will be required to participate in a variety of small-sided games during which a number of physiological and fitness variables will be monitored.

- Treadmill test – Your child will first get to complete a familiarisation session to get use to the laboratory, the treadmill running, and wearing the gas analysis equipment (this involves wearing a mouthpiece which is like wearing a swimming snorkel and a heart rate monitor around the chest).

Your child will perform a maximal exercise test on the treadmill to accurately measure their fitness (VO_{2max}). The test starts at an easy pace and then increases gradually until you cannot keep up with the speed. Your child will be asked to push themselves as hard as they can.

- Small-sided games – Your child will play a new small-sided game called Bucketball which involves passing a ball around to score a goal in the opposing team's bucket. Your child will play a variety of Bucketball games (12 in total) that will be differentiated by player numbers and duration. Your child will wear a GPS device to measure their heart rate and distance and speeds which they ran during the games. At the end of each game your child will be asked how hard they thought they worked from a chart given to them. All the games will also be video recorded to see how well your child performed skills during the game.



Above: 3 vs. 3 game of Bucketball

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What are the discomforts and risks?

Potential side effects may include:

- Fatigue and sore muscles - similar to those experienced after a hard training session or game.
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How will these discomforts and risks be eased?

During the maximal fitness test there will be attendants present who will be able to assist your child if they are feeling unwell. Within the facility there are staff members who are qualified in first aid, and there is a defibrillator available in case of an emergency. A telephone will also be on hand to call for immediate assistance if needed.

What are the benefits?

Following the study you will receive the outcome of your child's results in a written report. Therefore you will learn a lot about your child's individual fitness and how they can improve their training in the future. Your child will experience some new fitness techniques that are becoming more and more popular within team sport training environments.

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In the unlikely event of a physical injury as a result of your child's participation in this study, rehabilitation and compensation for injury by accident may be available from the Accident Compensation Corporation, providing the incident details satisfy the requirements of the law and the Corporation's regulations.

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What are the costs of participating in this research?

You will incur travel costs to LTAD as these will not be covered by the researcher. Your child will be required to undergo one test taking approximately 30 minutes and 12 games taking approximately 20 minutes each. Approximately half an hour will be required for a familiarisation session on the treadmill, and this will be done prior to the first test. This is to ensure the tests run smoothly. In this time you will also complete initial consent forms, and any queries you have will be answered verbally.

What opportunity do I have to consider this invitation?

- You may take the time you need and decide whether or not you would like your child to be involved
- You can stop your child's involvement in the project at any point.

How do I agree to my child participating in this research?

If you agree to your child participating you will need to fill out a consent form and have your child sign an accent form.

Will I receive feedback on the results of this research?

Yes, individual feedback will be provided to you. The group results will be used in a written report as part of my degree qualification (copy of report available upon request) and the study's findings may eventually be published in a scientific journal.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor:

Assoc. Prof. Andrew Kilding, Institute of Sport & Recreation Research New Zealand, School of Sport and Recreation, AUT University, Private Bag 92006, Auckland 1020, Ph 921 9999 ext. 7076, Andrew.kilding@aut.ac.nz

Concerns regarding the conduct of the research should be notified to the Executive Secretary, AUTEC, Madeline Banda, madeline.banda@aut.ac.nz, Ph 921 9999 ext 8044.

Whom do I contact for further information about this research?

Researcher Contact Details:

Craig Harrison, School of Sport and Recreation, AUT University / Millennium LTAD Coordinator ltad@mish.org.nz Ph 477 2012

Project Supervisor Contact Details:

Assoc. Prof. Andrew Kilding, Institute of Sport & Recreation Research New Zealand, School of Sport and Recreation, AUT University, Private Bag 92006, Auckland 1020, Ph 921 9999 ext. 7056, Andrew.kilding@aut.ac.nz

Approved by the Auckland University of Technology Ethics Committee on 09/05/2011

AUTEC Reference number 11/98

Parent / Guardian Information Sheet

Date Information Sheet Produced:
9 May 2011

Project Title
Effect of rule changes and conditioning blocks on the physiological, movement and skill demands of a generic catch and pass small-sided games in young athletes

An Invitation

Hi, my name is Craig Harrison. I am a PHD student at AUT University. My supervisor Assoc. Prof. Andrew Kilding and I would like to invite your child to help with a project that is investigating the best aerobic fitness training for young team sport athletes.

Please read the following and decide whether or not you would like your child to be involved. They don't have to be involved, and you can stop their involvement in the study at any time without any adverse consequences.

What is the purpose of this research?

It is important for team sport players to be fit to help them perform at their best during games. Traditionally fitness training involves long slow continuous or short fast interval running. However a different way to achieve the same results while much more enjoyable for athletes could be to play well prescribed small-sided games. Small-sided games are adapted from the original form of a sport that involve a reduced number of players and are designed for a specific purpose. Studies have demonstrated that small-sided games are effective at developing aerobic fitness in adults but we don't know how good they are at doing the same for young players. Therefore the purpose of this research is to examine the effectiveness of small-sided games for aerobic fitness development in young athletes.

How was your child chosen for this invitation?

Your child plays in a team sport and is within a year either side of their peak height velocity (PHV). PHV is the time during your child's physical development when they will be growing their fastest. Your child trains at least two times per week and competes in intermittent sports at least once per week.

What will happen in this research?

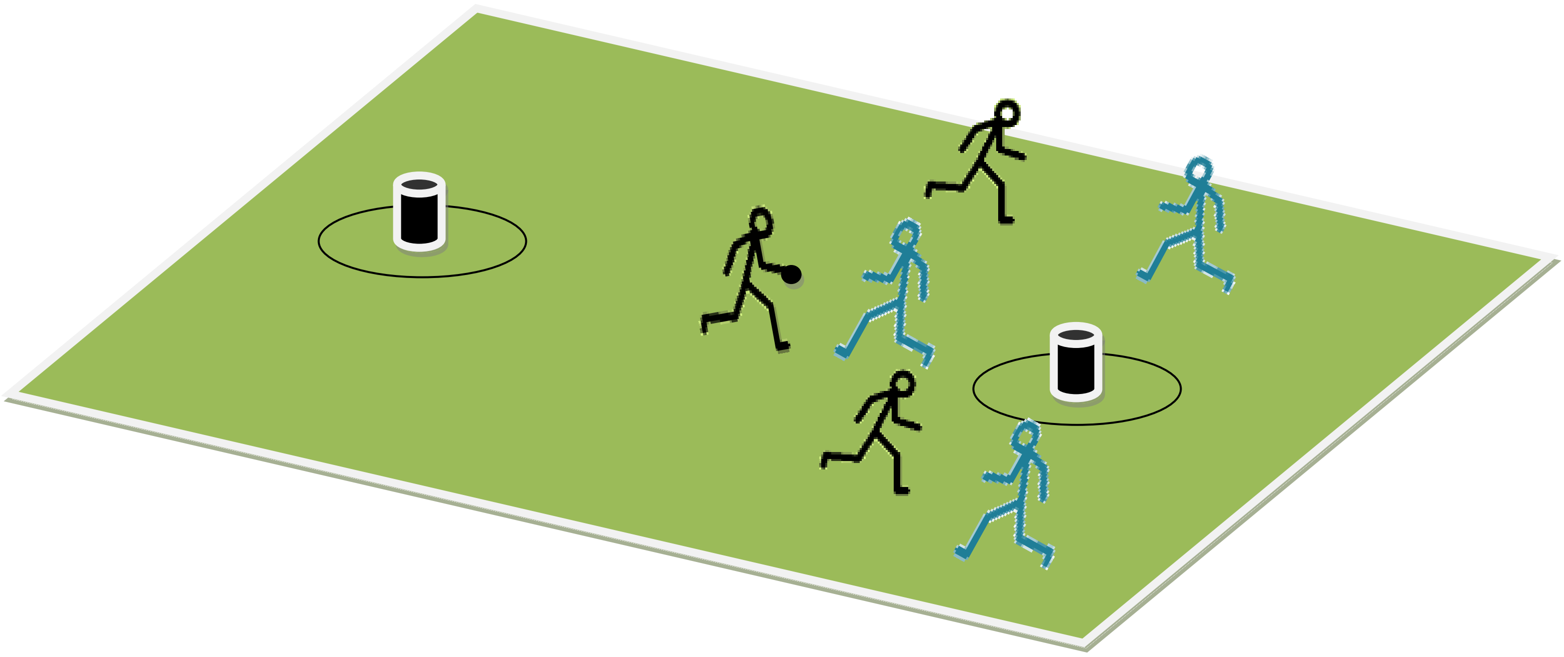
If you choose for your child to participate in this study, they will be required to perform two fitness tests and be taught some small-sided games in the first two weeks of the study. Then in the following three weeks they will be required to participate in a variety of small-sided games during which a number of physiological and fitness variables will be monitored.

- Treadmill test – Your child will first get to complete a familiarisation session to get use to the laboratory, the treadmill running, and wearing the gas analysis equipment (this involves wearing a mouthpiece which is like wearing a swimming snorkel and a heart rate monitor around the chest).

Your child will perform a maximal exercise test on the treadmill to accurately measure their fitness (VO_{2max}). The test starts at an easy pace and then increases gradually until you cannot keep up with the speed. Your child will be asked to push themselves as hard as they can.

- 30-15 intermittent fitness test – This test is similar to the beep test that your child may have completed before as part of their club or school training. The test involves running back and forth for 40 meters at specific speeds. A CD player will be used to set the pace using beeps. Between each 30 second shuttle run your child will receive a 15 second rest period before starting the next stage. They will be encouraged to push themselves as hard as they can and reach the highest score possible.

- Small-sided games – Your child will play a new small-sided game called Bucketball which involves passing a ball around to score a goal in the opposing team's bucket. Your child will play in variety of Bucketball games that will be differentiated by player number and games rules. They will also be required to complete some short, intermittent running as part of some of the games. Your child will wear a GPS device to measure their heart rate and distance and speeds which they ran during the games. At the end of each game your child will be asked how hard they thought they worked from a chart given to them. All the games will also be video recorded to see how well your child performed skills during the game.



Above: 3 vs. 3 game of Bucketball

Throughout the testing period your child will be asked to maintain their normal level of training but not do any very hard exercise the day before testing. Care will be taken to plan testing sessions around your child's training programme. The small-sided games will take place at the same time of the day during your child's normal training session. Your child will be asked to visit the Millennium of Sport and Health to complete their treadmill test at a time outside of these sessions. Finally, your child will be asked to wear the same footwear and similar clothing for each testing session.

What are the discomforts and risks?

Potential side effects may include:

- Fatigue and sore muscles - similar to those experienced after a hard training session or game.
- Dizziness and possible fainting from high levels of physical exertion - similar to those experienced after a hard training session or game.

How will these discomforts and risks be eased?

During the maximal fitness test there will be attendants present who will be able to assist your child if they are feeling unwell. Within the facility there are staff members who are qualified in first aid, and there is a defibrillator available in case of an emergency. A telephone will also be on hand to call for immediate assistance if needed.

What are the benefits?

Following the study you will receive the outcome of your child's results in a written report. Therefore you will learn a lot about your child's individual fitness and how they can improve their training in the future. Your child will experience some new fitness techniques that are becoming more and more popular within team sport training environments.

What compensation is available for injury or negligence?

In the unlikely event of a physical injury as a result of your child's participation in this study, rehabilitation and compensation for injury by accident may be available from the Accident Compensation Corporation, providing the incident details satisfy the requirements of the law and the Corporation's regulations.

How will your child's privacy be protected?

The information will remain in locked storage and will only be accessible to the researcher and the academic supervisors for this project. No-one will be able to identify your child from any of the summary findings for the report of the project as all information related to you will be coded. Information regarding your child's results will only be passed onto others with your permission.

What are the costs of participating in this research?

You will incur travel costs to LTAD as these will not be covered by the researcher. Your child will be required to undergo one test taking approximately 30 minutes and 12 games taking approximately 20 minutes each. Approximately half an hour will be required for a familiarisation session on the treadmill, and this will be done prior to the first test. This is to ensure the tests run smoothly. In this time you will also complete initial consent forms, and any queries you have will be answered verbally.

What opportunity do I have to consider this invitation?

- You may take the time you need and decide whether or not you would like your child to be involved
- You can stop your child's involvement in the project at any point.

How do I agree to my child participating in this research?

If you agree to your child participating you will need to fill out a consent form and have your child sign an accent form.

Will I receive feedback on the results of this research?

Yes, individual feedback will be provided to you. The group results will be used in a written report as part of my degree qualification (copy of report available upon request) and the study's findings may eventually be published in a scientific journal.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor:

Assoc. Prof. Andrew Kilding, Institute of Sport & Recreation Research New Zealand, School of Sport and Recreation, AUT University, Private Bag 92006, Auckland 1020, Ph 921 9999 ext. 7076, Andrew.kilding@aut.ac.nz

Concerns regarding the conduct of the research should be notified to the Executive Secretary, AUTEC, Madeline Banda, madeline.banda@aut.ac.nz, Ph 921 9999 ext 8044.

Whom do I contact for further information about this research?

Researcher Contact Details:

Craig Harrison, School of Sport and Recreation, AUT University / Millennium LTAD Coordinator ltad@mish.org.nz Ph 477 2012

Project Supervisor Contact Details:

Assoc. Prof. Andrew Kilding, Institute of Sport & Recreation Research New Zealand, School of Sport and Recreation, AUT University, Private Bag 92006, Auckland 1020, Ph 921 9999 ext. 7056, Andrew.kilding@aut.ac.nz

Approved by the Auckland University of Technology Ethics Committee on 09/05/2011

AUTEC Reference number 11/98

Parent / Guardian Information Sheet

Date Information Sheet Produced:
30 August 2012

Project Title
Efficacy of small-sided games to enhance aerobic fitness in young

An Invitation

Hi, my name is Craig Harrison. I am a PHD student at AUT University. My supervisor Assoc. Prof. Andrew Kilding and I would like to invite your child to help with a project that is investigating the best aerobic fitness training for young team sport athletes.

Please read the following and decide whether or not you would like your child to be involved. They don't have to be involved, and you can stop their involvement in the study at any time without any adverse consequences.

What is the purpose of this research?

It is important for team sport players to be fit to help them perform at their best during games. Traditionally fitness training involves long slow continuous or short fast interval running. However a different way to achieve the same results while much more enjoyable for athletes could be to play well prescribed small-sided games. Small-sided games are adapted from the original form of a sport that involve a reduced number of players and are designed for a specific purpose. Studies have demonstrated that small-sided games are effective at developing aerobic fitness in adults but we don't know how good they are at doing the same for young players. Therefore the purpose of this research is to compare the effectiveness of small-sided games with high-intensity, intermittent running for aerobic fitness development in young athletes.

How was your child chosen for this invitation?

Your child plays in a team sport and is within a year either side of their peak height velocity (PHV). PHV is the time during your child's physical development when they will be growing their fastest. Your child trains at least two times per week and competes in intermittent sports at least once per week.

What will happen in this research?

If you choose for your child to participate in this study, they will be required to perform a range of physical tests, twice (test and re-test) at the start and end of a six week training period. The tests include a treadmill test in the laboratory to determine aerobic fitness, the 30-15 intermittent fitness test, a jump test and a speed test. During the six week training period your child will be required to participate in one of two training interventions:

1. Small-sided game training twice a week for six weeks.

2. A combination of high-intensity, intermittent running and small-sided games training twice a week for six weeks

Physiological and fitness variables will be monitored during all training sessions. Details of specific tests are provided below.

- Treadmill test – Your child will be familiarised with the laboratory, the treadmill running, and wearing the gas analysis equipment (this involves wearing a mouthpiece which is like wearing a swimming snorkel and a heart rate monitor around the chest). Your child will perform a maximal exercise test on the treadmill to accurately measure his fitness (VO_{2max}). The test starts at an easy pace and then increases gradually until you cannot keep up with the speed. Your child will be asked to push themselves as hard as they can.

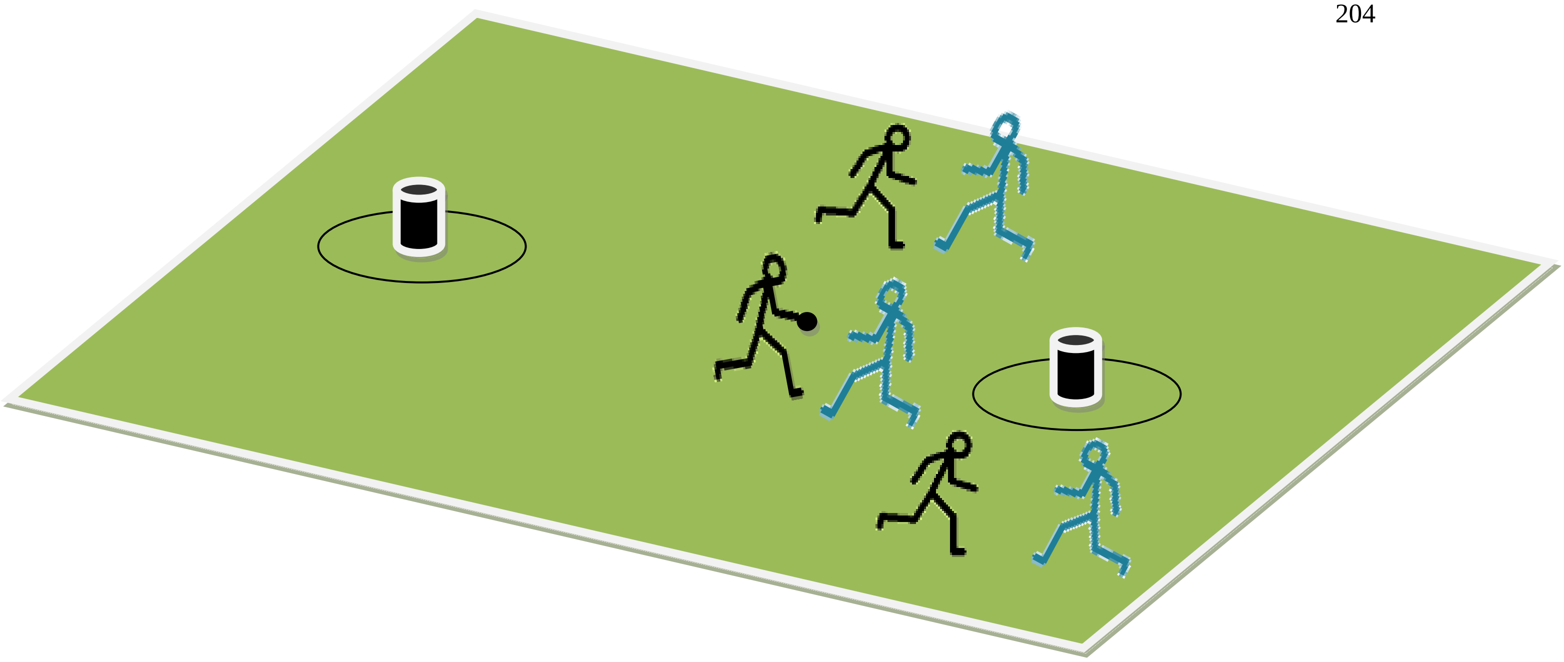
- 30-15 intermittent fitness test – This test is similar to the beep test that your child may have completed before as part of their club or school training. The test involves running back and forth for 40 meters at increasing speeds. A CD player will be used to set the pace using beeps. Between each 30 second shuttle run your child will receive a 15 second rest period before starting the next stage. They will be encouraged to push themselves as hard as they can and reach the highest score possible.

- Jump and speed test – Your child will complete a maximal jump test by standing on a force platform and jumping as high as they can, and a 30 m speed test by running as fast as they can between two sets of timing gates.

- Small-sided game training – Your child will play a new small-sided game called Bucketball which involves passing a ball around to score a goal in the opposing team's bucket (see below). Your child will wear a GPS device to measure their heart rate and distance and speeds run during the games. At the end of each game your child will be asked how hard they thought they worked from a chart given to them. All the games will also be video recorded to see how well your child performed skills during the game. Each small-sided game training session will last 20 minutes.

- High-intensity, intermittent running training and small-sided games – Your child will perform a combination of high-intensity, intermittent running and small-sided games for a period matched to

- the duration of the small-sided games only training.



Above: 3 vs. 3 game of Bucketball

Throughout the testing period your child will be asked to maintain their normal level of training but not do any very hard exercise the day before testing. Care will be taken to plan testing sessions around your child's training programme. The small-sided games and high-intensity running training will take place at the same time of the day during your child's normal training sessions. Your child will be asked to visit the Millennium of Sport and Health to complete their treadmill tests at a time outside of these sessions. Finally, your child will be asked to wear the same footwear and similar clothing for each testing session.

What are the discomforts and risks?

Potential side effects may include:

- Fatigue and sore muscles - similar to those experienced after a hard training session or game.
- Dizziness and possible fainting from high levels of physical exertion - similar to those experienced after a hard training session or game.

How will these discomforts and risks be eased?

During the maximal fitness test there will be attendants present who will be able to assist your child if they are feeling unwell. Within the facility there are staff members who are qualified in first aid, and there is a defibrillator available in case of an emergency. A telephone will also be on hand to call for immediate assistance if needed.

What are the benefits?

Following the study you will receive the outcome of your child's results in a written report. Therefore you will learn a lot about your child's individual fitness and how they can improve their training in the future. Your child will experience some new fitness techniques that are becoming more and more popular within team sport training environments.

What compensation is available for injury or negligence?

In the unlikely event of a physical injury as a result of your child's participation in this study, rehabilitation and compensation for injury by accident may be available from the Accident Compensation Corporation, providing the incident details satisfy the requirements of the law and the Corporation's regulations.

How will your child's privacy be protected?

The information will remain in locked storage and will only be accessible to the researcher and the academic supervisors for this project. No-one will be able to identify your child from any of the summary findings for the report of the project as all information related to you will be coded. Information regarding your child's results will only be passed onto others with your permission.

What are the costs of participating in this research?

You will incur travel costs to the Millennium Institute for the treadmill fitness tests as these will not be covered by the researcher. Your child will be required to undergo testing taking approximately 1 hour at the start and the end of the 6 week training period and 12 games taking approximately 20 minutes each (2 each week for six weeks). Familiarisation will be completed on the treadmill prior to the first test to ensure it runs smoothly. In this time any queries you have will be answered verbally.

What opportunity do I have to consider this invitation?

- You may take the time you need and decide whether or not you would like your child to be involved
- You can stop your child's involvement in the project at any point.

How do I agree to my child participating in this research?

If you agree to your child participating you will need to fill out a consent form and have your child sign an accent form.

Will I receive feedback on the results of this research?

Yes, individual feedback will be provided to you. The group results will be used in a written report as part of my degree qualification (copy of report available upon request) and the study's findings may eventually be published in a scientific journal.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor:

Assoc. Prof. Andrew Kilding, Institute of Sport & Recreation Research New Zealand, School of Sport and Recreation, AUT University, Private Bag 92006, Auckland 1020, Ph 921 9999 ext. 7076, Andrew.kilding@aut.ac.nz

Concerns regarding the conduct of the research should be notified to the Executive Secretary, AUTEC, Madeline Banda, madeline.banda@aut.ac.nz, Ph 921 9999 ext 8044.

Whom do I contact for further information about this research?

Researcher Contact Details:

Craig Harrison, School of Sport and Recreation, AUT University / Millennium Athlete Development Academy Director charrison@mish.org.nz Ph 477 2012

Project Supervisor Contact Details:

Assoc. Prof. Andrew Kilding, Institute of Sport & Recreation Research New Zealand, School of Sport and Recreation, AUT University, Private Bag 92006, Auckland 1020, Ph 921 9999 ext. 7056, Andrew.kilding@aut.ac.nz

Approved by the Auckland University of Technology Ethics Committee on 09/05/2011

AUTEC Reference number 11/98

Appendix 4: Parent consent forms

Parent/Guardian Consent Form

Title of Project: **Quantification of physiological, movement and skill demands during two different small-sided games in young athletes**

Project Supervisor: **Associate Professor Andrew Kilding**

Researcher: **Craig Harrison**

○ I have read and understood the information provided about this research project in the Information Sheet dated 9 May 2011

○ I have had an opportunity to ask questions and to have them answered.

○ I understand that I may withdraw my child/children and/or myself or any information that we have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.

○ If my child/children and/or I withdraw, I understand that all relevant information including tapes and transcripts, or parts thereof, will be destroyed.

○ I agree to my child/children taking part in this research.

○ I wish to receive a copy of the report from the research (please tick one): Yes○ No○

Child/children's name/s :

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Parent/Guardian's signature:

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Parent/Guardian's name:

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Parent/Guardian's Contact Details (if appropriate):

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Project Supervisor Contact Details:

Associate Professor Andrew Kilding

Institute of Sport & Recreation Research New Zealand

School of Sport and Recreation

Auckland University of Technology

Private Bag 92006

Auckland 1020

Ph 921 9999 ext. 7056

Andrew.kilding@aut.ac.nz

Approved by the Auckland University of Technology Ethics Committee on 09/05/2011

AUTEC Reference number 11/98

Parent/Guardian Consent Form

Title of Project: **Physiological, movement and skill demands of a generic catch and pass small-sided game in young athletes: effect of changing game duration and team player assignment**

Project Supervisor: **Associate Professor Andrew Kilding**

Researcher: **Craig Harrison**

○ I have read and understood the information provided about this research project in the Information Sheet dated 9 May 2011

○ I have had an opportunity to ask questions and to have them answered.

○ I understand that I may withdraw my child/children and/or myself or any information that we have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.

○ If my child/children and/or I withdraw, I understand that all relevant information including tapes and transcripts, or parts thereof, will be destroyed.

○ I agree to my child/children taking part in this research.

○ I wish to receive a copy of the report from the research (please tick one): Yes○ No○

Child/children's name/s :

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Parent/Guardian's signature:

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Parent/Guardian's name:

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Parent/Guardian's Contact Details (if appropriate):

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Project Supervisor Contact Details:

Associate Professor Andrew Kilding

Institute of Sport & Recreation Research New Zealand

School of Sport and Recreation

Auckland University of Technology

Private Bag 92006

Auckland 1020

Ph 921 9999 ext. 7056

Andrew.kilding@aut.ac.nz

Approved by the Auckland University of Technology Ethics Committee on 09/05/2011

AUTEC Reference number 11/98

Parent/Guardian Consent Form

AUT UNIVERSITY
TE WĀNANGA ARONUI O TAMAKI MAKAU RAU

Title of Project: **Effect of rule changes and conditioning blocks on the physiological, movement and skill demands of a generic catch and pass small-sided games in young athletes**

Project Supervisor: **Associate Professor Andrew Kilding**

Researcher: **Craig Harrison**

- ○ I have read and understood the information provided about this research project in the Information Sheet dated 9 May 2011
- ○ I have had an opportunity to ask questions and to have them answered.
- ○ I understand that I may withdraw my child/children and/or myself or any information that we have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.
- ○ If my child/children and/or I withdraw, I understand that all relevant information including tapes and transcripts, or parts thereof, will be destroyed.
- ○ I agree to my child/children taking part in this research.
- ○ I wish to receive a copy of the report from the research (please tick one): Yes○ No○

Child/children's name/s :

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Parent/Guardian's signature:

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Parent/Guardian's name:

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Parent/Guardian's Contact Details (if appropriate):

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Project Supervisor Contact Details:

Associate Professor Andrew Kilding

Institute of Sport & Recreation Research New Zealand

School of Sport and Recreation

Auckland University of Technology

Private Bag 92006

Auckland 1020

Ph 921 9999 ext. 7056

Andrew.kilding@aut.ac.nz

Approved by the Auckland University of Technology Ethics Committee on 09/05/2011

AUTEC Reference number 11/98

Parent/Guardian Consent Form

Title of Project: **Efficacy of small-sided games to enhance aerobic fitness in young**

Project Supervisor: **Associate Professor Andrew Kilding**

Researcher: **Craig Harrison**

- ○ I have read and understood the information provided about this research project in the Information Sheet dated 30/08/2012
- ○ I have had an opportunity to ask questions and to have them answered.
- ○ I understand that I may withdraw my child/children and/or myself or any information that we have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.
- ○ If my child/children and/or I withdraw, I understand that all relevant information including tapes and transcripts, or parts thereof, will be destroyed.
- ○ I agree to my child/children taking part in this research.
- ○ I wish to receive a copy of the report from the research (please tick one): Yes○ No○

Child/children's name/s :

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Parent/Guardian's signature:

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Parent/Guardian's name:

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Parent/Guardian's Contact Details (if appropriate):

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Project Supervisor Contact Details:

Associate Professor Andrew Kilding

Institute of Sport & Recreation Research New Zealand

School of Sport and Recreation

Auckland University of Technology

Private Bag 92006

Auckland 1020

Ph 921 9999 ext. 7056

Andrew.kilding@aut.ac.nz

Approved by the Auckland University of Technology Ethics Committee 09/05/0211

AUTEC Reference number 11/98

Appendix 5: Assent forms

Assent Form

Title of Project: **Quantification of physiological, movement and skill demands during two different small-sided games in young athletes**

Project Supervisor: **Associate Professor Andrew Kilding**

Researcher: **Craig Harrison**

- ○ I have read and understood the information sheet dated 9 May 2011 telling me what will happen in this study and why it is important.
- ○ I have been able to ask questions and to have them answered.
- ○ I understand that while the information is being collected, I can stop being part of this study whenever I want and that it is perfectly ok for me to do this.
- ○ If I stop being part of the study, I understand that all information about me, including the recordings or any part of them that include me, will be destroyed.
- ○ I agree to take part in this research.

Participant's signature:

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Participant's name:

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Participant Contact Details (if appropriate):

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Date:

Approved by the Auckland University of Technology Ethics Committee 09/05/0211

AUTEC Reference number 11/98

Assent Form

Title of Project: **Physiological, movement and skill demands of a generic catch and pass small-sided game in young athletes: effect of changing game duration and team player assignment**

Project Supervisor: **Associate Professor Andrew Kilding**

Researcher: **Craig Harrison**

- ○ I have read and understood the information sheet dated 9 May 2011 telling me what will happen in this study and why it is important.
- ○ I have been able to ask questions and to have them answered.
- ○ I understand that while the information is being collected, I can stop being part of this study whenever I want and that it is perfectly ok for me to do this.
- ○ If I stop being part of the study, I understand that all information about me, including the recordings or any part of them that include me, will be destroyed.
- ○ I agree to take part in this research.

Participant's signature:

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Participant's name:

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Participant Contact Details (if appropriate):

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Date:

Approved by the Auckland University of Technology Ethics Committee 09/05/0211

AUTEC Reference number 11/98

Assent Form

Title of Project: **Effect of rule changes and conditioning blocks on the physiological, movement and skill demands of a generic catch and pass small-sided games in young athletes**

Project Supervisor: **Associate Professor Andrew Kilding**

Researcher: **Craig Harrison**

- ○ I have read and understood the information sheet dated 9 May 2011 telling me what will happen in this study and why it is important.
- ○ I have been able to ask questions and to have them answered.
- ○ I understand that while the information is being collected, I can stop being part of this study whenever I want and that it is perfectly ok for me to do this.
- ○ If I stop being part of the study, I understand that all information about me, including the recordings or any part of them that include me, will be destroyed.
- ○ I agree to take part in this research.

Participant's signature:

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Participant's name:

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Participant Contact Details (if appropriate):

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Date:

Approved by the Auckland University of Technology Ethics Committee 09/05/0211

AUTEC Reference number 11/98

Assent Form

Title of Project: **Efficacy of small-sided games to enhance aerobic fitness in young**

Project Supervisor: **Associate Professor Andrew Kilding**

Researcher: **Craig Harrison**

- ○ I have read and understood the information sheet dated 30 August 2012 telling me what will happen in this study and why it is important.
- ○ I have been able to ask questions and to have them answered.
- ○ I understand that while the information is being collected, I can stop being part of this study whenever I want and that it is perfectly ok for me to do this.
- ○ If I stop being part of the study, I understand that all information about me, including the recordings or any part of them that include me, will be destroyed.
- ○ I agree to take part in this research.

Participant's signature:

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Participant's name:

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Participant Contact Details (if appropriate):

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Date:

Approved by the Auckland University of Technology Ethics Committee 09/05/0211

AUTEC Reference number 11/98

Appendix 6: Abstracts

Chapter 3: Abstract

The aim of this study was to quantify the physiological responses, time-motion characteristics and technical executions associated with a novel non sport-specific SSG in young team sport players. On six separate occasions, twelve young male team sport athletes (mean ± SD: age,13.0 ± 0.3 years, height, 157.4 ± 4.9 cm, body mass, 47.0 ± 5.0 kg and $\dot{V}O_{2\ peak}$, 55.1± 4.6 ml·kg^{-1}·min^{-1}) completed various 'bucketball' SSG formats (i.e. 3 vs. 3, 4 vs. 4 and 6 vs. 6) twice each. Heart rate (HR) was measured during each SSG at 5 s intervals. Time-motion characteristics were measured using global positioning systems. Ratings of perceived exertion (RPE) were recorded immediately after the SSGs using the Borg scale (RPEs, 6 – 20). Technical skill executions were measured using a high-speed digital video camera. Analysis revealed a tendency for the 3 vs. 3 games to elicited higher heart rates (88.3 ± 4.3) than either 4 vs. 4 (85.9 ± 4.9) or 6 vs. 6 formats (85.9 ± 3.2). Total distance travelled at 13 – 17.9 km·hr^{-1} was more during 6 vs. 6 than 3 vs. 3 games (very likely substantial true difference, 97%), and total possessions and number of catches, passes and shots were all higher in 3 vs. 3 compared with 4 vs. 4 and 6 vs. 6 games. There was no different for RPE between game formats. The results of this study indicate that 3 vs. 3 non sport-specific SSGs provide higher stimulus for aerobic fitness adaptation and technical improvement than 4 vs. 4 and 6 vs. 6 formats and their use for training young team sport athletes is recommended.

Chapter 4: Abstract

This study aimed to quantify and compare the physiological, physical and technical demands of a sport-specific and non sport-specific small-sided game (SSG) in young athletes. Ten male soccer players (mean ± SD: age, 13.0 ± 0.3 years, $\dot{V}O_{2peak}$, 54.4 ± 4.9 ml·kg^{-1}·min^{-1}) completed 3 vs. 3 and 6 vs. 6 soccer and 'bucketball' SSGs twice. Games lasted 16 min and were performed in randomised order at least 48 hours apart. Movement patterns and heart

rate were measured using 4 Hz global positioning systems. Technical skill executions were assessed by video analysis and ratings of perceived exertion (RPE) using the Borg scale (RPEs, 6 – 20). Total distance (4.9 ± 4.1% and 8.3 ± 6.6%), distance at 7 – 12.9 $km \cdot hr^{-1}$ (14.5 ± 12.5% and 14.9% ±16.1), total possessions (14.7 ± 18.0% and 12.9 ± 18.9%) and percent successful passes (24.1 ± 11.7% and 30.1 ± 17.6%) were higher for bucketball compared to soccer (3 vs. 3 and 6 vs. 6, respectively). Total distance at 13 – 17.9 $km \cdot hr^{-1}$ was higher for 6 vs. 6 than 3 vs. 3 bucketball (32.3 ± 21.2%). There was likely substantial difference for $\%HR_{peak}$ (89.5 ± 3.1 vs. 87.4 ± 2.8 $b \cdot min^{-1}$) and time above 90% HR_{peak} (570 ± 288 s vs. 361 ± 288 s) between bucketball and soccer (3 vs. 3 and 6 vs. 6, respectively). Young players travelled further at higher overall speeds, experienced higher physiological workloads, and performed more successful technical executions during the non sport-specific SSG.

Chapter 5: Abstract

To determine the effects of manipulating team selection strategy and playing regime on physical and skill outputs during a non sport-specific SSG in young athletes, twelve young rugby players (mean ± SD: age, 13.2 ± 0.5 years, height, 165.6 ± 10.1 cm, body mass, 59.8 ± 16.9 kg and $\dot{V}O_{2peak}$, 60.0 ± 4.6 $ml^{-1} \cdot kg^{-1} \cdot min$) completed continuous (16 min) and intermittent (4 x 4 min and 8 x 2 min) 3 vs. 3 “bucketball” SSGs twice, balanced and unbalanced for team player allocations. Movement patterns and heart rate were measured using 4 Hz global positioning systems. Technical skill executions were assessed by video analysis and ratings of perceived exertion (RPE) using the Borg scale (RPEs, 6 – 20). Analysis revealed higher $\%HR_{peak}$ (88.2 ± 1.2 vs. 86.8 ± 1.7) and time spent above 90% HR_{peak} (546 ± 116 s vs. 446 ± 158 s) for balanced compared to unbalanced games. Distance travelled above 18 $km \cdot hr^{-1}$ during balanced SSGs exceeded unbalanced games (ES = 0.57). Team selection strategy had no effect on skill executions. Percent HR_{peak} for continuous, balanced games (90.6 ± 1.6%) exceeded intermittent, balanced games (86.9 ± 1.9% and 85.8 ± 1.5% for 4 x 4 min and 8 x 2 min, respectively). RPE were higher for 16 min (15.0 ± 1.4) compared to 8 x 2 min (14.0 ± 0.8) but not 4 x 4 min (14.5 ± 1.5) games. Effective receives were higher for 16 min compared to 4 x 4 min games (ES = 0.47). Young players experienced higher physiological loads during continuous SSGs balanced for team selection and travelled further at higher speeds during balanced games. Finally, SSG format had little effect on the quantity and quality of technical executions.

Chapter 6: Abstract

The aim of this study was to examine the acute physiological and perceptual responses, time-motion characteristics and technical skill executions associated with rule changes and the inclusion of inter-game conditioning exercise during a non-specific SSG in young athletes. Ten team sport players aged 13.7 ± 0.5 years (mean ± SD) completed various 16 min 3 vs. 3 “bucketball” SSGs differentiated by games rules (no change, BB; man-on-man marking, BB^{MM}; 3 sec possession, BB^{3S}) or by inclusion of two individualised, high-intensity running bouts (8 x 15 s @ 100% of the final running velocity of the 30-15 intermittent fitness test (V_{IFT}, BB^{HR}), separated by 15 s of passive rest). Movement patterns, heart rate and body load were measured using 4 Hz global positioning systems. Technical skill executions were assessed by video analysis and ratings of perceived exertion (RPE) using the Borg scale (RPEs, 6 – 20). Analysis revealed $\%HR_{peak}$ and time spent ≥90% HR_{peak} for BB substantially exceeded all other formats. Inter-game conditioning exercise increased distance travelled at speeds ≥18 $km \cdot hr^{-1}$ substantially (624 ± 137, 64.5 ± 55.1, 45.5 ± 27.7, 63.3 ± 28.3 for BB^{HR}, BB, BB^{3S} and BB^{MM}, respectively). Body load was also substantially higher for BB^{HIR} compared to all other SSG formats. Number of ball involvements, total passes and receives for BB^{3S} substantially exceeded all other SSG formats (effect sizes = 0.62-1.67). In summary,

SSGs with no adjustment to the rules elicited higher intensities. However rule manipulation led to an increase in the quality and quantity of technical executions and increased the distance players travelled at higher running speeds. Our findings allow refinement of training prescription in young athletes and assist coaches with achieving their desired training outcomes

Chapter 7: Abstract

This study investigated the effect of non-specific game-based training (GT) versus a mix of non-specific game-based training and high-intensity interval training (MT) on physical performance characteristics in young athletes. Twenty-six male team sport players (13.9 ± 0.3 years) were assigned to either GT (n=13) or MT (n=13) for six weeks. Game-based training consisted of 2 x 8-11 min 3 vs. 3 'bucketball' SSGs separated by 3 min passive rest twice per week, while MT consisted of one SSGs session and one high-intensity running session of 15 s runs at 90-95% of the speed reached at the end of the 30-15 intermittent fitness test (V_{IFT}) interspersed with 15 s passive recovery. Groups were matched for exercise duration at each training session. Body load (BL), HR and RPE were measured during training and maximal oxygen uptake ($\dot{V}O_{2peak}$), V_{IFT}, jump height (VCMJ), and speed were assessed pre- and post-training. Body load and HR were higher during MT compared to GT (363 ± 23 au·min^{-1} vs. 321 ± 20 au·min^{-1} and 91 ± 2.3% vs. 88. 6 ± 1.3%, for BL and HR respectively). Following training, $\dot{V}O_{2peak}$ (5.5 ± 3.3%; effect size, large) improved only after MT, whereas V_{IFT} improved after MT (6.6 ± 3.2%; effect size, large) and GT (4.2 ± 5.5%, ES = small) albeit to differing degrees. Sprint time over 5 m improved only after GT (effect size, small), while 20 m sprint and VCMJ were unchanged in both groups. In conclusion, while MT and GT were both effective at increasing performance parameters, greater effects were seen following MT.

Therefore, MT should be considered as the preferred training method for improving aerobic power in young team sport athletes.