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**THE DEVELOPMENT OF A RELIABLE AND
VALID NETBALL INTERMITTENT ACTIVITY
TEST**

A thesis presented in partial fulfilment of the requirements for
the Degree of
Master of Science
in
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New Zealand

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ABSTRACT

The purpose of the present investigation was to identify the exercise intensity of netball match play in order to assist in the development of a Netball Intermittent Activity Test (NIAT). A further aim was to assess the criterion validity and the test-retest reliability of the NIAT. Eleven female netball players (21.4 ± 3.1 years, 1.73 ± 0.06 m, 69.3 ± 5.3 kg and 48.4 ± 4.9 ml·kg⁻¹·min⁻¹ mean \pm SD, age, height, body mass and $\dot{V}O_{2max}$, respectively) volunteered to participate in the study. Heart rate data was recorded for all participants from at least two full 60 minute games during Premier Club competition. Individual maximum heart rate values were acquired for all subjects from the performance of the Multistage Fitness Test, and used to transform heart rate recordings into percent maximum heart rate (%HR_{max}). Patterns in %HR_{max} were used to indicate positional grouping when developing the NIAT from time motion analysis data. Subjects performed two trials of the NIAT separated by at least seven days. Physiological and performance markers were measured systematically throughout the NIAT. Exercise intensity as denoted by %HR_{max} significantly decreased from the first half of match play to the second half ($90.4 \pm 2.7\%$ v $88.3 \pm 2.8\%$; $p < 0.05$). Significant differences ($p < 0.05$) were observed between positional groups and led to the grouping of Defence (D), Centre Court (CC), and Attack (A) players for NIAT performance. Comparisons of %HR_{max} between match play and NIAT performance indicated that the NIAT had good criterion validity for D (*match Mdn* = 92.52% vs. *NIAT Mdn* = 86.27%, $p > 0.05$) and A (*match Mdn* = 86.95% vs. *NIAT Mdn* = 82.93%, $p > 0.05$) players, but that %HR_{max} during the NIAT (*Mdn* = 79.70%) was significantly lower than match play (*Mdn* = 89.70%) for CC group ($p < 0.05$). Measures of 5 m sprint performance (1.27 ± 0.06 s v 1.25 ± 0.06 s; $p > 0.05$; $r = 0.66$, $p < 0.001$), vertical jump height (29.12 ± 4.17 cm v 28.82 ± 3.60 cm; $p > 0.05$; $r = 0.91$, $p < 0.001$), circuit time (107.49 ± 3.22 s v 107.89 ± 4.27 s; $p > 0.05$; $r = 0.72$, $p > 0.001$) and %HR_{max} ($82.56 \pm 4.66\%$ v $81.03 \pm 4.13\%$; $p > 0.05$; $r = 0.82$, $p < 0.001$) for NIAT1 vs. NIAT2 indicated good test-retest reliability. These data suggest that netball players experience a reduction in exercise intensity over the duration of a game, with exercise intensity being related to on-court position. Whilst the NIAT appears to be a repeatable activity pattern, it is not a good simulation of physiological strain for all positional groups. More work is required in order to create a netball simulation that is both reliable and valid for all players.

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CHAPTER I

INTRODUCTION

Netball is New Zealand's top sporting activity for females with registered members totaling more than 120,000 in over 1000 clubs nationwide (Netball New Zealand [online]). The game requires explosive movements such as short, fast sprints, quick stops, and many changes in direction (Neal & Sydney-Smith, 1992). The physiological stress experienced by a player during a game will vary with numerous factors, including the playing environment, the opponents' skill, and the closeness of the match (Steele & Chad, 1991), which all cause variation in movement patterns during a game. The unpredictable nature of netball game-play could be one reason for the absence of intervention research on netball match performance.

Athletes, trainers, and coaches often need to invest a considerable amount of time researching the physiological aspects of their sport while striving to improve performance (Cronin et al., 2001). This is particularly difficult in team situations where it may not be possible to assess every athlete individually. If all players can be assessed in a similar way during a test that is not time intensive this would be a huge advantage to the coach. If this test could be developed to investigate other factors that could improve performance, for example training regimes or dietary intervention, it would give trainers another advantage in the development of optimum performance. Furthermore, if this test replicated the physiological demands of a game it could act as a training tool for coaches

to ensure their athletes are adequately prepared for the physiological aspect of the particular sport.

Current intervention research into netball uses various methods of assessment to investigate physiological aspects of netball including basic sprinting movement (O'Donoghue and Cassidy, 2002), and sprints on a cycle ergometer (Blee et al., 1999). Although these studies give informative results about elements of individual physiological fitness in netball players, the testing methods appear to lack ecological validity because they do not fully represent the movement patterns involved in a game of netball. Other authors have investigated tests for specific netball activities such as chest passing (Cronin et al., 2001) and agility (Farrow et al., 2005). However, intervention research into the game as a whole is scarce, possibly because of the lack of structure during the game. Therefore, there appears to be a need for the development of a controlled simulation that could be used for the assessment of training regimes and selected interventions. This study aims to design a Netball Intermittent Activity Test (NIAT) through the use of previous time motion analysis data (Steele & Chad, 1991). This study aims to further quantify the physiological demands of netball match play by recording heart rate data, and utilize these data to validate the NIAT. To ensure the NIAT is a simulation of actual netball activity validity will be assessed against a criterion measure of physiological strain. Any simulation developed will need to be repeatable on any one occasion in order that any physiological differences observed are due to interventions rather than a change in exercise intensity. Therefore, an attempt will also be made to establish the reliability of the NIAT.

1.1 Hypotheses

The primary null hypotheses for the present investigation were:

H01: Mean %HR_{max} will not differ between quarter and positional group during competition games.

H02: Mean %HR_{max} will not differ between competition games and the NIAT.

H03: Mean %HR_{max}, sprint times, jump heights and circuit times will not differ between NIAT Trials.

H04: Sprint and jump performance will not change throughout the duration of the NIAT.

CHAPTER II

REVIEW OF LITERATURE

2.1 Introduction

Research into the physiological demands of netball is relatively rare within the current sport science literature. Investigations have often focused on other intermittent sports such as soccer, rugby and hockey, drawing conclusions relevant to these games. Although these sports are structurally different from netball, they all share a common intermittent nature and as such lend themselves to comparison. The first section of this literature review will cover the physiological demands of team sports similar to netball in order to highlight the activity profile of intermittent sport. A review of the current netball physiological literature will be presented to identify links with other intermittent activity profiles. Researchers have further attempted to replicate the demands of intermittent profiles by creating laboratory and field-based simulations; the final section of the review will attempt to describe and critique some of these simulations.

2.2 Physiological demands of intermittent running exercise

Intermittent activity profiles are found in field and court games where two or more players are participating for example soccer, hockey, rugby, and racquet sports. These sports are characterized by periods of maximal or near maximal intensity effort followed by lower intensity periods, often of short duration (see Glaister, 2005 for a detailed

review). The physiological demands of intermittent exercise are often more complex than continuous sports such as running (Bangsbo, 1993; Drust et al., 2000b), and place unique demands on muscle metabolism because supply of energy is required for multiple functions, being needed for both contraction of muscles, and restoration of homeostasis (Balsom et al., 1992). Various methods have been used to record data on the physiological demands of intermittent sports with the earliest being time motion analysis. The development of better technology over time has allowed for sport-specific measurement of physiological aspects of sport in the field e.g. portable heart rate monitors (Ali & Farrally, 1991; Larsson, 2003). The measurement of physiological markers during match play has resulted in the production of more descriptive data about the physiological stress experienced during team games, to support the previous match analysis data. Although there are some time motion analysis data for netball in the literature, there is very little information on the physiological stresses experienced during the game.

2.2.1 Distance covered

Authors often report data on total distance covered during team sports when performing time motion analysis. There is great variation among male sports with studies on rugby union reporting total match distances of 4-7 km (Deutsch et al., 1998), rugby league research reporting 6-8 km (Meir et al., 1993), while soccer players complete longer distances of 8-12 km (Van Gool et al., 1988; Mohr et al., 2003; Rampini et al., 2007a; 2007b). Similar distances of approximately 10.5 km have been reported for female soccer players (Krustrup et al., 2005). Racquet sport athletes cover lesser distances, depending on the length of the game, with badminton players covering up to 2 km (Liddle

et al., 1996). Many of these studies used athletes of similar professional or elite caliber and employed similar time motion analysis methods and so should, theoretically, be comparable. The variance in total distance covered between intermittent sports is likely a reflection of the difference in playing time. For example, soccer players appear to cover the largest distances and also have the longest games times at 90 minutes. Racquet sports may vary considerably on reported distances covered as games will last for as long as it takes for victory. Larger distances covered in field sports versus court games may also be a reflection of playing surface area, with football, rugby and hockey pitches being considerably larger than basketball, tennis and badminton courts. A netball game typically lasts 60 minutes and the court surface area is similar to that in basketball. Therefore, it seems likely that netball players will cover longer distances than racquet sport athletes but shorter distances than athletes in sports such as rugby union and soccer, which are performed on larger fields of play over longer durations.

There is evidence in the literature of large inter- and intra-individual variations in the distances covered in intermittent sports. The intra-individual variation may be attributed to positional variations identified in rugby union (Deutsch et al., 1998), rugby league (Meir et al., 1993), and soccer (Mohr et al., 2003; Rampini et al., 2007a). This is also likely to be the case in netball where positional play is strongly evident. Although distance covered has often been used to estimate energy expenditure during a game (Drust et al., 2007), the very nature of intermittent sports makes this estimation problematic since the intensity at which the distances are covered is not taken into account.

2.2.2 Speed and intensity of player activity

Variation in the total distances covered by different positional groups has been analysed further to indicate that there is also disparity in the intensity covered over those distances (Deutsch et al., 1998; Mohr et al., 2003). It is often the distance covered at high-intensity that distinguished positional groups, and also class of player as elite players covered larger distances at a high intensity than sub-elite players (Mohr et al., 2003). In addition, there was a reduction in total distance covered and distance covered at high-intensity in the second half or toward the end of each half of the game (Lothian & Farrally, 1994; Mohr et al., 2003; Krstrup et al., 2005). However, two of these studies only used one game for analysis (Lothian & Farrally, 1994; Mohr et al., 2003), which could mean that the observed fatigue could be a reflection of that particular game only. However, these results do give us a clearer picture of the physiological demands of intermittent sports by indicating that fatigue appears to result in an attenuation of high-intensity activity towards the end of the game despite seemingly long periods of aerobic-type activity. This may also be the case in netball match play, although the shorter match time and the presence of quarter breaks in play during a netball match may negate the fatigue effect shown in other intermittent sports.

Many authors report data from time motion analysis as the percentage of total time spent in different activity categories (Mayhew & Wenger, 1985; Docherty et al., 1988; Spencer et al., 2004; Duthie et al., 2005; Rampini et al., 2007a). This allows for better comparison between intermittent sports as it takes the difference in match duration into account.

Aerobic, low-intensity activity makes up varying proportions of total game time in intermittent sports. Reported values include 85% in rugby union (Docherty et al., 1988); 90% in rugby league (Meir et al., 1993); 88% in soccer (Mayhew & Wenger, 1985); 94% in Australian rules football (Dawson et al., 2004); 87% in male field hockey (Spencer et al., 2004); and 78% in female field hockey (Lothian & Farrally, 1994). These proportions exhibit some variation between the various different sports. In contrast, the high-intensity or anaerobic proportion of activity is much more variable ranging from 5.6% in male field hockey (Spencer et al., 2004) to 21.9% in female field hockey (Lothian & Farally, 1994). These differences may be due to the definition of high-intensity activities within the time motion analysis with some authors including game specific activities (Docherty et al., 1988; Meir et al., 1993; Lothian & Farrally, 1994), and some simply classifying running-only type activities (Mayhew & Wenger, 1985; Dawson et al., 2004; Spencer et al., 2004). The different activity profiles in these studies may also be a result of different research practices. For example, some authors only collated time motion analysis data for one game (Lothian & Farally, 1994; Spencer et al., 2004), potentially resulting in the intensity profile reflecting that game only and not the sport as a whole. Other authors presented data from two or more games (Dawson et al., 2004; Docherty et al., 1988; Mayhew & Wenger, 1985; Meir et al., 1993) giving more depth to the intensity profile for the particular sport. In addition, the skill differences between the sports often make it difficult to compare them with each other, for example the high level of body contact in rugby union may result in a weakened comparison to lower-body contact sports such as hockey and soccer.. However, the low-intensity periods of work are important in terms of recovery from the high-intensity intervals and so in this respect it is not surprising that many intermittent sports exhibit similarly high proportions of aerobic activity compared

to high intensity activity. As an intermittent sport, it could be expected that in netball, low-intensity effort will be similar in proportion to other intermittent sports and equally important in recovery from high-intensity activity.

There appears to be a continuing trend in intermittent sport motion analysis of positional differences in match activity, identified in rugby union (Docherty et al., 1988; Deutsch et al., 1998; Duthie et al., 2005), rugby league (Meir et al., 1993), soccer (Rampini et al., 2007a), Gaelic football (McErlean et al., 2000) and hockey (Spencer et al., 2004). This is an interesting observation since these sports are played on a field that is relatively large and players are not limited to one specific area by the rules of the game as they are in netball. However, in their study on Super 12 rugby games Duthie and Colleagues (2005) recognized the activity differences as an indication of the high level of specificity required in certain positional roles within the game, for example the activity profile of the Forwards was strongly affected by the frequency of efforts involving static exertion (rucks, mauls and scrums). This would indicate that it is not only the area of activity and distance covered that determines the physiological response to intermittent sport, but also the type and nature of the activity or skill performed. It would be likely that netball would have similar position-specific differences to rugby since netball is position-specific in nature, with different roles being assigned to each position in the game. Because the role of a Defender in netball is noticeably different from a Shooter, it follows that their observed activity patterns will also differ. For example, the action of shooting should never be observed for Defenders since only Goal Shooter and Goal Attack are permitted to shoot under the rules of the game. Similar to the findings from Duthie and colleagues

(2005) that static exertions increase total work it could be that certain static exertions such as defense of a shot (by the Goal Defence and Goal Keeper) add more to the exertion profile of these positions than other players on court.

2.2.3 Energy requirements

Many team sports with intermittent activity patterns last for an hour or more (Glaister, 2005) and have changes in activity on average every 4-6 seconds (Spencer et al., 2004; Stroyer et al., 2004; Krstrup et al., 2005). As previously mentioned, this complex nature often makes the physiological profile more demanding than continuous-style sports (Bangsbo, 1993). A further elevation to energetic cost is the constant need for team sport players to be involved in stopping, starting, turning and changing activity. Energy expenditure is elevated in backwards and sideways running when compared to forwards running (Reilly, 1997), which indicates that netball match play would have an elevated energetic cost compared with running as a result of activities such as stopping, starting, and running backwards, which are common in a netball game.

A large proportion of the energy cost data from intermittent sports is obsolete, and recent studies are scarce. However, some authors have attempted to use the heart rate-oxygen uptake ($HR-\dot{V}O_2$) relationship determined from laboratory testing and heart rates recorded during game play to estimate energy expenditure from individual $HR-\dot{V}O_2$ regression equations (Ali & Farally, 1991; Coutts et al., 2003). It has been suggested that this method is likely to over-estimate energy expenditure as a result of the effects that other factors such as ambient conditions, psychological strain, and static activities will

have on heart rate during intermittent sports (Reilly, 1997). However, it has been used in non-steady state exercise (Bot & Hollander, 2000) and also soccer (Bangsbo, 1993), where individual HR- $\dot{V}O_2$ regression equations generated $\dot{V}O_2$ values that were not significantly different from measured values. Therefore, it may be possible to estimate the energetic cost of netball from individual HR- $\dot{V}O_2$ regression equations.

2.2.3.1 Aerobic contribution

Individual HR- $\dot{V}O_2$ regression equations applied to heart rate data collected during match play have indicated the average exercise intensity of intermittent sports including female soccer at 77% $\dot{V}O_{2max}$ (Krustrup et al., 2005), and rugby union at 80% $\dot{V}O_{2max}$ (Coutts et al., 2003). Significantly lower values were observed during tennis (Christmass et al., 1998; Smekal et al., 1998; Ferrauti et al., 2001) and badminton (Majumdar et al., 1997) match play with estimates of between 50-70% $\dot{V}O_{2max}$ over the duration of the game, perhaps further reflecting the effects of lesser game duration and playing area. Ogushi and colleagues (1993) did attempt to estimate work intensity during soccer match-play using a portable, modified Douglas bag system. This study reported lower values than studies using HR- $\dot{V}O_2$ relationships (47% $\dot{V}O_{2max}$ to 61% $\dot{V}O_{2max}$), but the results were not fully representative of either a full game or the full population cohort since expired gas collection only occurred during small portions of the game, and only two student participants were used. Further, the results collected from these two individuals may have been limited by the restrictive nature of wearing Douglas bag equipment while playing soccer. Because results were unclear it is still difficult to say how netball would compare with other intermittent sports. However, the duration of netball and the size of

playing area involved in a game indicate it may fall between racquet sports and field sports at around 70% $\dot{V}O_{2\max}$.

Heart rate is a good indicator of circulatory strain during intermittent sports and so can give an estimate of the type and intensity of exercise performed (Drust et al., 2007). Heart rate responses to match play in intermittent sports are more widely published, particularly in soccer where mean values ranging from 152-186 beats·min⁻¹ have been reported (Ali & Farally, 1991; Stroyer et al., 2004; Krstrup et al., 2005; Edwards & Clark, 2006). This range appears to be associated with the level of player studied with two studies reporting that elite players exhibited higher mean match heart rates than their recreational counterparts (Edwards & Clark, 2006; Stroyer et al., 2004). Mean heart rate values for rugby league and basketball players also fall within a similar range to soccer players at around 165 beats·min⁻¹ (Coutts et al., 2003) and 171 beats·min⁻¹ (Abdelkrim et al., 2007) respectively, whereas tennis players appear to report slightly lower mean heart rate values in the range of 140-155 beats·min⁻¹ (Bergeron et al., 1991; Smekal et al., 1998), another possible reflection of the differences in playing area and match duration between field and court sports. However, much of these data are difficult to compare since they are not related to a criterion measure such as a proportion of maximal heart rate (HR_{\max}). Some authors have sought to report this information as well, with mean documented values of 86% HR_{\max} in soccer (Krstrup et al., 2005; Edwards & Clark, 2006); 81% HR_{\max} in tennis (Christmass et al., 1998; Smekal et al., 1998); 89% HR_{\max} in basketball (McInnes et al., 1995); 87% HR_{\max} in badminton (Liddle et al., 1996; Majumdar et al., 1997); and 84% HR_{\max} in rugby league (Coutts et al., 2003). Large

ranges are seen within sporting disciplines, often due to the calibre and age of the subjects used. For example, the study by Edwards and Clark (2006) revealed that professional soccer players work at a higher percentage of HR_{max} over the duration of the game than their recreational counterparts and so are probably better able to withstand higher absolute physiological strain throughout the duration of a game. This links back to time motion analysis data on the speed and intensity of intermittent sport players in that elite players often exhibit higher levels of high intensity running than sub-elite players (Mohr et al., 2003). It is suggested a similar situation exists in netball with elite players working at a higher overall intensity than their recreational counterparts.

Some authors have reported heart rate data that reflect patterns in the time motion analysis data, with heart rates differing between the first and second halves of the game. This indicates a reduction in intensity since normally heart rate would normally increase over the duration of exercise as a result of cardiovascular drift (Ali & Farrally, 1991; Edwards & Clark, 2006). However, this trend was not observed in female soccer games (Krustrup et al., 2005) or in rugby league (Coutts et al., 2003), where mean heart rate values did not differ between game halves in those study populations. The clarity of this intensity pattern is further complicated by the fact that all of the above studies only collected heart rate data during one match in their respective sports. This could mean that the observed patterns were a reflection of that particular game only and not of the sport as a whole. The observation of variation in activities performed by different positional groups was further supported by Deutsch and colleagues (1998) who illustrated positional variations in the time spent in prescribed heart rate zones in rugby union games.

Therefore, it is expected that heart rate data from netball game play will exhibit similar patterns to the time motion analysis data already available in the literature and so would be a suitable basis for development of a simulation.

2.2.3.2 Anaerobic contribution

Time motion analysis data from the current literature indicate that the physiological profile of intermittent sports has a fairly low anaerobic contribution to the energy supply. However, it has been recognized that the ability to perform this anaerobic element of the game consistently can be a crucial performance outcome (Stroyer et al., 2004). Blood lactate concentration has been used as an indication of anaerobic contribution to energy requirements because lactate is a product of the anaerobic glycolytic pathway. Some authors have reported mean values of lactate concentration at cessation of game play in rugby union of 2.8 mmol·l⁻¹ (Docherty et al., 1988), soccer as 3.7 mmol·l⁻¹ (Edwards & Clark, 2006), and tennis as 2.3 mmol·l⁻¹ (Bergeron et al., 1991). These values suggest that these intermittent sports do not require a large anaerobic energy contribution. The lactate values collated could be an indication of the large aerobic contribution to intermittent sports. Periods of low intensity work within intermittent profiles allow for clearance of lactate possibly built up during high intensity work. Researchers in sports such as rugby union, rugby league and basketball have attempted to take further measurements during natural breaks in play, indicating a larger contribution to match play activity from anaerobic metabolism with values of lactate concentration ranging from 4.8-8.4 mmol·l⁻¹ (McInnes et al., 1995; Deutsch et al., 1998; Abdelkrim et al., 2007; Coutts et al., 2003). Other studies have indicated peak values of lactate concentration from 7 mmol·l⁻¹ to >10 mmol·l⁻¹ in singles tennis (Christmass et al., 1998), soccer (Bangsbo,

1997), rugby league (Coutts et al., 2003) and rugby union (McLean, 1992; Deutsch et al., 1998), which indicate a more substantial anaerobic contribution to the energetic demands of intermittent sports. However, blood lactate values will only reflect the work done in the five minutes prior to taking the blood sample (Bangsbo, 1997). These higher reported lactate values indicate, therefore, that at some point during these games the lactate threshold is breached but that the lower intensity periods allow for clearance of lactate to allow players to continue performing higher intensity intervals. Results taken during rugby league match play give a slightly clearer picture of the anaerobic energy profile of the sport, for example first half values of lactate concentration ($8.4 \pm 1.8 \text{ mmol}\cdot\text{l}^{-1}$) being higher than second half ($5.9 \pm 2.5 \text{ mmol}\cdot\text{l}^{-1}$) (Coutts et al., 2003) reflected a drop-off in intensity of activity which supported the findings from analysis of time-motion and heart rate data from rugby league observations. It appears that physiological data from other intermittent sports often reflects patterns in the intensity profile of time motion analysis data. Therefore, it appears likely that physiological data in the form of heart rate collected from netball match play will reflect the time motion analysis data observed for netball match play.

2.3 Physiological Demands of Netball

Netball can be classified as an intermittent sport because it includes short fast sprints and frequent changes in direction in the activity profile (Neal & Sydney-Smith, 1992). The game is played on a court of 15.25 m by 30.5 m, the length being divided into thirds. Players are restricted to specific areas of the court; the Centre is allowed in all thirds,

players with Attack or Defence in the title in two consecutive thirds, while Goal Shooters and Goal Keepers are only permitted in one third of the court. Therefore, activities often occur over short distances and there appears to be a highly explosive nature to the game with many quick movements and jumps or leaps (Steele & Milburn, 1987), which indicates that netball has an important anaerobic energy contribution and should reflect this pattern in activity data. The following section will describe the nature of netball by examining the small amount of physiological netball data that currently exists. By examining any differences between netball and other intermittent sports a conclusion can be reached on the importance of a netball-specific activity simulation.

2.3.1 Positional patterns

Because netball is played on a relatively small court and the rules of the game restrict player movement on court, it could be said that each of the seven positions has its own set of physiological characteristics, and some authors have presented data to reflect this (Otago, 1983; Woolford & Angove, 1991; 1992). However, many authors have found patterns in various collected data, including anthropometric, fitness attribute and time motion analysis data, which indicate that positional grouping may be possible. The most common method has been to group attacking (Goal Shooter [GS] and Goal Attack [GA]), centre-court (Centre [C], Wing Attack [WA] and Wing Defence [WD]), and defending players (Goal Defence [GD] & Goal Keeper [GK]) (Bale & Hunt, 1986; Chad & Steele, 1991; Steele & Chad, 1991; Cooper et al., 2002), although other potential patterns have been identified (Allison, 1978; Otago, 1983). The common groups have often been based on positional similarities in data such as height and mass, and skill differences between the groups. Significant differences have been identified between positional groups in

physiological data among the intermittent sports such as rugby union and soccer that have larger areas of activity. In netball match play it would be expected that the discrete positional patterns of play governing the game and the individual skills required by each position will lead to netball players exhibiting positional differences in physiological and activity data

2.3.2 Physical characteristics

Many netball studies have investigated the physical characteristics of players of various ability. Netball players have been identified as being taller and heavier than female players in other sports (Withers & Roberts, 1981), and similar in stature to elite female basketball players (Bale & Hunt, 1986). The literature indicates that the height of netball players has a large range from 1.63 m to over 1.80 m, with a trend for elite (i.e. State and National) players to be taller than club or “successful” players (Barham & Wilson, 1981; Bale & Hunt, 1986; Chad & Steele, 1991; Neal & Sydney-Smith, 1992; Blee et al., 1999; Hopper et al., 1999; Cronin et al., 2001; Fallon et al., 2001; Cooper et al., 2002). There are also positional variations in height with defence and attack players often being taller than centre-court players (Bale & Hunt, 1986; Chad & Steele, 1991; Cooper et al., 2002). It has been identified that taller players execute certain skills more successfully, including rebounding, defending shots and intercepting (Chad & Steele, 1991).

The importance of body mass to sports like netball with an explosive element is related to the power-to-body weight ratio (Chad & Steele, 1991). Body mass data for netballers indicate a range of 60-71 kg (Barham & Wilson, 1981; Chad & Steele, 1991; Neal &

Sydney-Smith, 1992; Blee et al., 1999; Cronin et al., 2001; Fallon et al., 2001; Cooper et al., 2002). However, the trend towards greater body mass with increasing standard of player was only shown in one study (Hopper et al., 1999) and was absent from another (Bale & Hunt, 1986). It may be the case those playing at a higher standard will exhibit a higher power-to-body weight ratio than those playing at a lower standard and that it is this that separates their ability rather than their absolute body mass. There was also a trend for attackers and defenders to exhibit greater body mass than centre court players (Bale & Hunt, 1986; Cooper et al., 2002), although this was probably related to their larger stature. Previous authors have indicated that there were no differences in body fat mass between positional groups (Bale & Hunt, 1986), supporting the idea that the extra mass of attacking and defensive players is a result of their larger stature and not of increased adiposity.

2.3.3 Maximal Oxygen Uptake

Relatively few authors have sought to quantify the aerobic power of netball players at any level, although there is some indication that maximal oxygen uptake among representative netball players is lower than that for representative hockey players (Withers & Roberts, 1981). It would appear that aerobic power of netball players lies in the range of 42-49 ml·kg⁻¹·min⁻¹ (Withers & Roberts, 1981; Chad & Steele, 1991; Blee et al., 1999; O'Donoghue & Cassidy, 2002), although data from various groups of athletes in Australia has indicated a range from 33 ml·kg⁻¹·min⁻¹ to 62 ml·kg⁻¹·min⁻¹, depending on the level of player with elite players in the upper range (Ellis et al., 2000). Netballers appear to have similar maximal oxygen uptake values to athletes in other female sports such as basketball (38-61 ml·kg⁻¹·min⁻¹), hockey (36-65 ml·kg⁻¹·min⁻¹), soccer (35-61

ml·kg⁻¹·min⁻¹), and tennis (41-57 ml·kg⁻¹·min⁻¹) (Ellis et al., 2000). However, more recent data on the netball population are needed to complement these findings in order to give us a clearer picture of the aerobic power of modern day netball players. This is particularly important in the wake of changes to the game. For example, most modern netball matches are 60 minutes in length; previous research has been based on 40 minute games (Otago, 1983). Changes such as this may have altered the physiological make-up of the netball population over time.

2.3.4 Leg power

Leg power data for netball players are also relatively scarce, which is concerning because the explosive nature of the game could mean that leg power is an important component of superior performance. Jumps are often made to catch passes or to intercept a high ball from an opponent, and so it follows that the ability to jump higher could improve performance in these skills. Those authors who have tested for leg power have often used different methods, making the data hard to compare. Withers and Roberts (1981) found that the representative players in their cohort had an average power of 953 W (approximately 13 W·kg⁻¹ body mass) using sprinting up a flight of stairs at 58% incline as an assessment. Light gates recorded time taken from the 8th to the 12th stair (a total vertical distance of 0.661 m); with vertical velocity and power calculated from the distance and relevant time values. The authors indicated that netball players exhibited a significantly higher absolute power output than female hockey and softball players (813.4 W and 800.7 W respectively), which was probably indicative of the more explosive type movements such as changes of direction and jumps in netball compared with other female intermittent sports. Blee et al. (1999) recorded power output during a 10 second maximal

effort cycle ergometer test and obtained power: mass ratios of around $15 \text{ W}\cdot\text{kg}^{-1}$ body mass. This difference from the Withers and Roberts (1981) study was not only a probable consequence of a different test population but also a result of the different methods used to assess power output.

Other methods of assessing leg power have included the use of vertical jump and sprint data, which are more game-relevant assessments because the movements are performed during match play. Vertical jump data have been reported in some studies, but again results are difficult to compare because different methodologies and equipment were used. It appears that elite netballers jump between of 42 and 44 cm during jump and reach tests (Blee et al., 1999; Chad & Steele, 1991). Sprint data for netballers are also relatively scarce. One study indicated that National players sprinted 20-metres in 3.6-3.8 seconds (O'Donoghue & Cassidy, 2002). However, the relevance of assessing a 20-metre sprint is unclear as time motion analysis data from netball match play indicates that players only sprint on average for 0.1-0.6 s (Steele & Chad, 1991). This sprinting activity is likely to occur when trying to lose an opponent or make an interception, and so the faster these movements are made the more successful the performance outcome. Therefore, it is likely that assessing sprint speed over a shorter distance would be more applicable.

2.3.5 Activity patterns

The activity profile of netball players has been described by both time motion analysis and actual physiological data collection. A large proportion of the time motion analysis

data are obsolete, and some even take the form of simple observations rather than scientific time motion analysis (Allison, 1978). One of the first main time motion analysis studies (in Queensland, Australia in 1983) took the form of coding video tape of games involving three international teams in a tri-test series (Otago, 1983). The activity categories used were basic consisting of shuffle, sprint, slow jog, pass, guard, defend and goal. General observations indicated that the majority of activity time was spent shuffling, and that there was a wide range in the proportion of the game spent sprinting (6.7-36.3% of total time). The data also indicated that the percentage of total game time spent in possession of the ball was between of 7.5 and 18.8%. However, the data indicated differences among individual positions and identified the activity profile for each position. The relatively clear picture of movement patterns for the game that emerged may not be relevant to the modern game because the match was played as two 20-minute halves whereas today a game would be played as four 15-minute quarters. The video recording used to collate the time motion analysis data originated from a television broadcast and was not recorded specifically for the purpose of the study. This meant that there were times when players were not in view of the camera and certain assumptions were made about the activity patterns outside of camera view. These included assumptions that unless a player moved into view of the camera to receive a pass, they were not performing any vigorous activity. This may have led to an underestimation of the proportion of vigorous activity for all positions, but particularly those who were out of vision more regularly.

In 1991 Steele and Chad carried out time motion analysis on a 60 minute game, and also used more detailed activity analysis categorising activities as locomotor (standing, walking, jogging, running, sprinting, shuffling) and non-locomotor (shooting, pass, centre pass, catch, toss up, jump, leap, rebound, defend, guard). The video recording was specifically for the analysis of activity for this study and ensured that players were always in view of one of the two cameras. They reported data in terms of repetitions of the activity; average time spent in activity and percent total game time in that activity and split groups into centre court (C), shooters (S) and defenders (D). Overall, the highest proportion of match time was spent standing or walking forward, although positional differences were seen. Centre court players spent significantly less time standing (C 22.3% vs. S 38.3% vs. D 35.8%) and more time jogging (C 13.8% vs. S 5.6% vs. D 4.8%) and running (C 3.3% vs. S 2.0% vs. D 1.0%), while shooters spent significantly less time walking forward (S 21.8% vs. C 28.9%) than centre-court players. According to these data the proportion of game time spent sprinting was 0%, which differed significantly from the findings of the earlier study. It was, however, recognized that sprinting did occur in the number of repetitions data, and the proportion merely reflected that sprinting was a minor activity when listed with the many locomotor and non-locomotor activities identified in the game. The short-distance over which sprints occur during a netball game may also have meant that sprint movements may have been missed when the data were coded thereby underestimating the amount of game time spent sprinting. Interestingly the total mean contribution of non-locomotor movements involving ball possession (pass, catch, toss up, shoot) was a maximum of 5.5% of total game time for any one player, which was approximately three minutes of an entire match. The majority of the time was

spent in locomotor activity with defenders spending the most time in non-locomotor activity without the ball at 14.6% total game time.

In order to assess the actual physiological strain associated with a netball game Woolford and Angove have published two research articles examining heart rates recorded during netball matches (Woolford and Angove, 1991; 1992). The earlier article compared match data to those collected during training sessions, while the latter article presented the same data examining positional specific trends within game play. Participants were three members of a regional senior team competing in a National titles tournament. The maximum heart rate (HR_{max}) of each subject was determined using an incremental treadmill test in order to convert match heart rate data to $\%HR_{max}$. The time spent in one of four intensity zones shown in Table 1 was calculated. The results show that in the court positions observed (WA, GA, C & WD) there were differences in the time spent in each heart rate zone, with GA spending the most time in Zone 1. However, the authors did recognise that the three games used to capture the data for GA were the most closely contested three out of the nine games studied during the tournament. They also reported high intra-individual differences in time spent in heart rate zones when a person remained in the same playing position (as much as 25% more time spent in the highest heart rate zone), and when players changed positions during the game there was also a difference in time spent in heart rate zone. For example, when one player started a game at WA and moved to C at half time her overall game intensity was lower compared with games in which she played C first and/or when she played C or WA for the whole game. However, because a full set of results in terms of playing positions and matches were not studied, it

is impossible to say if these results show a clear outcome of the effect of changing position on game intensity. The study did give some insight into the physiological strain experienced by players during netball games by indicating the mean time spent in various heart rate zones, which could correlate with exercise intensity and how hard the player is working. However, a more comprehensive data set, which would include all playing positions, would be required for a more complete picture.

Table 2.1 Heart Rate Intensity Zones (Woolford & Angove, 1991; 1992)

| | Limits | Physiological definition |
|---------------|---------------|--|
| Zone 1 | > 95% HRmax | Indicative of maximal oxygen uptake |
| Zone 2 | 85-95% HRmax | Zone where individual anaerobic threshold occurs |
| Zone 3 | 75-85% HRmax | Zone where lactate threshold occurs |
| Zone 4 | < 75% HRmax | Aerobic zone |

The relatively small amount of netball physiology research available indicates that while the game does have similarities to other intermittent sports, there are also some clear differences specifically in the movement patterns performed during a netball game. It could be said that netball has its own discrete set of movements, particularly power-based movements such as jumping and leaping to catch passes and to make interceptions, which set it aside from other intermittent sports. Therefore, it would not be plausible to utilize a simulation based on time motion analysis data from intermittent sports such as soccer, rugby union or field hockey to investigate the physiology of netball. A separate simulation based only on time motion analysis data from netball games has merit.

However, since this type of simulation does not yet exist in the scientific literature it will be necessary to examine simulations from other intermittent sports in order to gain an insight into design techniques that have proven successful for previous researchers.

2.4 Models for Simulating High-Intensity Exercise

The most ecologically valid way of assessing the effects of an intervention on an aspect of an individual's physiology during a sport is to apply the intervention to a real game setting. However, research indicates that the intensity and type of movement experienced in intermittent sports varies because of factors such as the opposition and ambient conditions (Steele & Chad, 1991), which makes it difficult to assess whether changes in physiological variables between one match and the next are a result of the intervention or simply a result of differing match intensities. Difficulty in assessing the efficacy of interventions in intermittent sports has led to the development of various simulations that aim to closely replicate the demands of the intermittent sport for which they were developed. These simulations are usually based on time motion or physiological data for a specific sport or a combination of both. It has been recognized that these tests are necessary to establish the benefits of intervention techniques in the form of nutritional, ergogenic or physical training aids (Deutsh et al., 1998; Alricsson et al., 2001).

2.4.1 Laboratory based models

Repeated bouts of high-intensity activity are easily replicated in the laboratory situation and have often been the focus of intermittent exercise research (Balsom et al., 1992) mainly because of the presence of well-controlled conditions such as ambient

environment and consistency in equipment and surroundings (Drust et al., 2000b; Larsson, 2003). The laboratory offers a level of control over these factors that minimizes any affect they may have on the outcomes of the research.

A treadmill simulation based on estimated exercise intensities observed during competitive singles tennis was designed by Christmass and colleagues (1999). The test lasted for 90 minutes with subjects running a work: rest circuit at a speed corresponding to 120% $\dot{V}O_{2peak}$ for 12 seconds and resting completely for 18 seconds many times over. The study did not make comparisons between match data and the simulation to indicate the validity of the simulation. However, the authors did suggest that the mean heart rate response for the intermittent profile in the study ($\sim 89\% HR_{max}$) was fairly close to that in match play ($\sim 83\% HR_{max}$) from a previous study (Christmass et al., 1998) indicating that exercise intensity was similar in both conditions. However, the fact that the rest periods were static may reduce the validity of this simulation because it is unlikely that a tennis player will stand perfectly motionless between rallies or points for the time used in the simulation. The musculature involved in tennis match-play will also be largely different to that involved whilst purely running, particularly with respect to the movements made by the upper limbs in hitting the ball. It would follow therefore that a sport such as netball will involve different muscle groups to carry out movements such as jumping and throwing to those involved in just running, and that these movements should be included in a simulation.

Testing the efficacy of treadmill-based tests was the focus of two investigations into tennis, with slightly different methodologies. Smekal and colleagues (2000) examined the differences in performing incremental testing procedures on a treadmill versus a field situation. Results indicated that measurements of heart rate and $\dot{V}O_2$ at the individual anaerobic threshold were significantly higher in the field-based test (mean HR 175 beats·min⁻¹; mean $\dot{V}O_2$ 47.8 ml·kg⁻¹·min⁻¹) than those seen on the treadmill (mean HR 165 beats·min⁻¹; mean $\dot{V}O_2$ 44.4 ml·kg⁻¹·min⁻¹). Similarly, Ferrauti et al. (2001) showed that, when working at the same proportion of $\dot{V}O_{2max}$, mean measurements of heart rate (140 vs. 126 beats·min⁻¹), lactate concentration (1.53 vs. 1.01 m·mol⁻¹), blood glucose concentration (5.45 vs. 4.34 m·mol⁻¹) and respiratory exchange ratio (0.93 vs. 0.88) were significantly higher during a tennis match than during a treadmill run. Both these studies indicate that the metabolic profile of intermittent sports is different from running on a treadmill, with game activities exhibiting a strong emphasis on glycolysis (through evidence of lactate production as a by-product) and glycogenolysis (as a consequence of the high intensity nature of the activity profile) as energy sources in tennis. It follows that a treadmill-based test may not be appropriate to simulate the metabolic effects of netball.

A soccer-specific intermittent test was developed by Drust and colleagues (2000b) and performed on a treadmill. It was based on movement activities observed by Reilly and Thomas (1976). Activity patterns included walking, jogging, cruising and sprinting, and each was given its own discrete speed. The test was split into two 22 ½ minute cycles consisting of 23 discrete activity bouts: six each of walking and jogging, three cruises and eight sprints. These activity patterns were performed in a non-cyclical order, although

predominantly with high-intensity exercise preceding a period of low-intensity exercise. The original test involved performing this cycle twice in order to replicate one 45-minute half of a soccer game and it has since been modified to represent a full 90-minute game (Drust et al., 2000a). In this way the test replicates both the time and activity based elements of a soccer game, while the estimated energy expenditure value of 68% $\dot{V}O_{2max}$ falls very close to those previously cited for intermittent sports. This test has been used as an investigative tool by various soccer researchers (Drust et al., 2000a; Rahnama et al., 2003; Clarke et al., 2005; Sari-Sarraf et al., 2006). However, the authors themselves recognise the limitations of the test in that there are no game skills such as kicking and tackling, there are fewer activity changes than those seen in a soccer game, and utility movements such as moving sideways and backwards are omitted. There is also the absence of the acceleration and deceleration phases of changes in direction. The use of a motorized treadmill in this study meant that the running activity differed from that experienced during soccer because athletes often alter stride length and stride frequency to cope with treadmill running (Riley et al., 2008), and made assessment of any power decrements in high intensity exercise over the course of the test difficult. This issue could have been rectified by the introduction of a non-motorized treadmill for assessment of sprint running (Lakomy, 1987). While testing the efficacy of the non-motorized treadmill for analyzing sprint performance Lakomy (1987) found similarities between free-running and sprinting on the non-motorized treadmill. However, there were also major differences including a 20% decline in maximal sprint speed from free running to treadmill sprinting. While it may be possible to replicate intermittent activity profiles on a treadmill in terms of intensity, they will lack ecological validity because the very

movements that define the sport in question are absent. Therefore, a netball simulation must be performed in such a way that sideways, backwards and diagonal movements can be performed along with forward running.

Further barriers to the use of laboratory based protocols for team sport participants include expense and accessibility, and poor transfer of results from these tests to physical performance in specific sports (Alricsson et al., 2001). Many laboratory based tests use activities such as cycle ergometry or running in a single direction that are not a true representation of the movement or muscle activity patterns of intermittent team sports and do not measure sport-specific performance (Smekal et al., 2000; Ferrauti et al., 2001; Larsson, 2003). Hoffman and colleagues (1996) noted that the inclusion of upper body exercise into a lower body test elicits substantially different physiological responses, resulting in differences in the measured values of parameters, including an elevated $\dot{V}O_2$ at a given power output. This would indicate that cycling protocols are not ideal for the physiological assessment of free-running activities, and therefore would not be appropriate to simulate a netball game.

In summary, although laboratory based simulations are useful for research in a controlled environment, they are probably not applicable to intermittent sports due to the lack of specific movement patterns involved in these sports and the extra inertial energy required to change these movement patterns at regular intervals. This has repercussions for the

ecological validity, muscle use and metabolic profile observed in the simulation and that observed in the intermittent sport in question.

2.4.2 Shuttle running simulations

Many authors have recognized the difficulty in replicating physiological aspects of intermittent sports in controlled laboratory settings and have concluded that field testing is often more valid and relevant to the sport concerned (Bergeron et al., 1991; Ferrauti et al., 2001; Cronin & Owen, 2004). Based on this conclusion many authors have attempted to create simulations in environments with greater ecological validity.

A soccer simulation aimed at replicating the conditions of a game of high intensity was developed in Europe by Rico-Sanz and colleagues (1999). The simulation was deemed to be more demanding than an average soccer game, mainly because the lack of walking elevated the overall intensity of exercise. Participants were required to run at three different velocities representing the activities of running, jogging and sprinting over 15-metre shuttles. Players performed three 30-metre laps of running, one lap of jogging and one of sprinting, totaling 150-metres with the total distance taking one minute to complete. Stopwatches were used to test for velocity compliance and to time the sprint performance. Termination of the test occurred when 30-metre sprint time exceeded 7 seconds or when the subject reached volitional fatigue (decided they could not carry on). The authors indicated that the test could be applied when comparing soccer-specific endurance levels between players since it reported a time point for exhaustion, a measure which is often difficult to assess during actual games. The test was also reported to

represent the activities and frequency of the changes in those activities during matches. Group heart rate during the test fluctuated between 160-200 beats·min⁻¹, reflecting a similar profile to that seen in other soccer match play research. Limitations in the test include the absence of a standing or walking rest period, although the protocol was originally designed to be high-intensity, as indicated through recognition by the authors that it is significantly more demanding than a normal soccer game. Also, fatigue in the original study occurred, on average, around 42 minutes. This is not representative of a full soccer game and will have limited application to intervention studies looking at full game performance. The protocol has been used to research aspects of fatigue (Rico-Sanz et al., 1999; Zehnder et al., 2001), and this appears to be its main application. Therefore, this would only be a reliable model on which to base a netball simulation if it was designed to investigate fatigue.

At Loughborough University in the UK, Nicholas and colleagues (1995; 2000) used descriptive data from previous match analysis to design a field test to simulate the activity pattern of a full soccer game called the Loughborough Intermittent Shuttle Test (LIST). The LIST was similar to the test set up by Rico-Sanz et al. (1999), although the LIST used a 20-metre distance and walking activity was included. Three shuttles of 20-metres were completed for each of walking, jogging and cruising activities, with the latter two being based on running speeds that would elicit 55% and 95% of a subject's $\dot{V}O_{2max}$, respectively. Sprinting consisted of one 20-metre shuttle, followed by four seconds of active recovery (walking) to prepare for the next shuttle. Intensity of exercise was strictly controlled by the presence of an audio signal indicating the half-way point and the end of

a shuttle. This circuit was repeated for 15 minutes, followed by a rest period of three minutes and each 15-minute block was repeated five times, representing 75 minutes of activity. The LIST has since been modified by adding an extra 15-minute period to represent a full 90-minute game (Ali et al., 2007a; Backhouse et al., 2007; Foskett et al., 2008). The LIST has shown good test-retest reliability and appears to replicate soccer match play both on an activity level (total distance covered - 11.1km; number of sprints – 55-60; and turns completed ~600) and on a physiological level (blood lactate concentrations – 5.7-6.2 mmol·l⁻¹; mean heart rates – 169-171 beats·min⁻¹) (Nicholas et al., 2000). There is no soccer-specific or utility activity in the protocol such as running backwards and time spent dribbling and passing. The authors recognised that energy expenditure would be increased during these activities because running while dribbling a soccer ball increases the net energetic cost by 5.2 kJ·min⁻¹ compared to running at the same speed without a ball over a range of speeds (Reilly & Ball, 1984). However, match analysis data failed to report the percentage of game time spent in possession of the ball possibly because it represented a small proportion of the match. In a review of soccer data, Reilly (1997) mentioned that distance covered with the ball by top class players often equated to less than 2% of total distance. Nicholas et al. (2000) concluded that the LIST protocol could be a useful research tool since it maintains control over both the environment and the pattern of exercise, both of which are often compromised in the match situation. The LIST has since been used to assess the physiological effect of various intervention strategies (Ali et al., 2007a; Backhouse et al., 2007; Foskett et al., 2008), and modified for use as a performance test to differentiate between standard of player (Edwards et al., 2003). As a result of the similarities in movement patterns and

physiological observations between the LIST and soccer match play, it is a good model on which to base a simulation for other intermittent sports including netball.

In order to address the absence of a ball in many of the soccer-specific simulations Bishop and colleagues (1999) developed a protocol with the inclusion of a ball. They based the activity patterns on data collected from a previous study by Bangsbo et al. (1991), calculating approximate distances from mean time and speeds for each activity. A simple protocol of cyclical activity patterns was then designed for use in a field setting. The shuttle was 50 metres in length and each cycle contained the following activities: 1 shuttle dribbling a ball through cones, 1 shuttle backwards running, ½ shuttle cruising, ½ shuttle sprinting, 1 shuttle walking. On completion of each shuttle participants moved 5 metres to the side, although the intensity of this movement was not specified. This meant that an additional 15-metre walk was required at the end of the circuit to return to the starting point. Each circuit lasted just over two minutes, was performed seven times (totaling 15 minutes) and the 15-minute exercise bouts were separated by a one and a half minute rest period. This was repeated three times to represent half of a soccer match, followed by a 15-minute rest period and then performed again to represent the second half of the game. Total distance covered during the test was reported to be slightly less than during the LIST (Nicholas et al., 2000) but still representative of previously reported soccer data. At $167 \text{ beats}\cdot\text{min}^{-1}$ heart rate data for the simulation compared well with previous data. The use of ball contact and some backwards motion addressed some of the energy expenditure issues seen with other protocols, although there was still an absence of other soccer-specific activities such as heading, tackling and jumping, which would

have further increased energy expenditure. Ball contact occurred for a distance of roughly 2 km, possibly over-estimating the proportion of game-time spent with the ball at the feet, and as a result match play energy expenditure may have been overestimated using this simulation. This study highlighted the difficulties of including ball contact in an intermittent activity test and may provide some justification for excluding this aspect of a sport from a simulation.

Researchers in sports other than soccer have also attempted to create simulations of game conditions. Time motion analysis data from first-class rugby union games formed the basis of a test designed by Deutsch at the University of Otago, New Zealand (2001). The simulation was not purely a running protocol like those created for soccer, but consisted of a circuit of 11 different stations performed 14 times. Activities performed on the stations were a 20-m linear sprint, a 22-m agility sprint (offensive sprint), 4 walking stations, a dynamic drive using a dynamometer cart, a 33-m agility sprint (defensive sprint), a 31-m agility sprint (tackle sprint – included use of a tackle bag), ball passing at a target (passing accuracy) and a 30 m linear sprint. Simulation of a game was achieved by splitting the 14 circuits into two 40-minute halves with a 10-minute rest at half-time. Subjects were given 30 seconds to complete each of the 11 stations, with any extra time left being given as rest. Rugby union can be considered a highly skilled game, with a relatively high proportion of game time spent in static exertion type activities by certain groups of players (Deutsch et al., 1998). It would seem, therefore that this test is a good replication of the activities involved in rugby game play, and it has since been used to assess the ergogenic affects of caffeine on performance (Stuart et al., 2005). However,

there is relatively little comparison with the actual physiological stress associated with a rugby game, particularly the different modes of running intensity. Although the total distance covered during the test at sprinting intensity was close to that reported in the literature at around 700 m, there was also a further contribution to high intensity exercise from speed-agility activity. This may mean players were working at a higher overall exercise intensity during the protocol than they would in a game. Development of a simulation needs to take into account the movement patterns used to replicate high intensity activity. This is especially pertinent in netball where straight sprinting appears to contribute relatively little to the overall activity pattern despite the presence of other high intensity movement (Steele & Chad, 1992).

Rugby union and soccer are both intermittent sports where the time for completion of the game is set and extra time is only added on for injury breaks or in tournament situations to determine a winner. For racquet sports this is not the case, and games can vary in length quite considerably. Davey and colleagues (2003) attempted to design a simulation for tennis match play based around match analysis data. Players performed 11 sets each consisting of a service game (3 minutes 16 s consisting of serves and groundstrokes) followed by a long recovery (1 minute 30 seconds) followed by a receiving game (3 minutes 10 s consisting of groundstrokes and recovery) followed by a short recovery (30 seconds). The total time taken to complete this protocol was 92 minutes 46 seconds, which compared favorably with the minimum match length reported from observations by the authors of actual match play of 95 minutes 28 seconds. However, this was only the minimum match length and games could exceed this time significantly. Therefore,

extending the length of the test would make it more closely replicate the average match length to better cover all possible game durations. It is possible that by using the minimum match length the authors were only replicating the easier games, which were perhaps completed more quickly because of a weak opponent. However, by applying an intervention to an average game an overall picture of the effect of that intervention on the particular intermittent sport may be gained. The authors did conclude, that the simulation had been successful in replicating the intermittent character of tennis, and that heart rate measurements during the simulation were very similar to those reported in previous tennis match data.

Kingsley and colleagues (2006) created two versions of a squash simulation, one to simulate average match play, and one to quantify squash-specific fitness. Both versions required players to move to one of eight pre-determined court positions with a racquet in hand using squash-specific footwork patterns determined from previous notational analysis. At each court position the participant played a simulated stroke and then returned to a central “T” position on court. Tight control was maintained over the pattern and speed of all movements by the use of pre-recorded audio signals. During the squash-simulation players completed four rallies of eight strokes (each with a different length and movement pattern), repeated six times to represent a game of approximately 12 minutes in duration. The authors found that, compared to intense match play, the simulation exhibited similar results in terms of length of play, physiological responses (mean heart rate – 179 vs. 180 beats·min⁻¹; mean blood lactate concentration – 1.8 vs. 3.5 mmol·l⁻¹) and perceived exertion (14 vs. 17). They then used the results from the multi-stage

squash test (MST) to establish that the squash-specific fitness of their subjects was similar in order to support their findings and confirm that the physiological responses to the original protocol were a result of the activities performed and not different levels of fitness. The MST was similar to the simulation, with rallies consisting of one minute stages. However, the time allowed to reach the simulated-shot court position was incrementally reduced with each subsequent stage until players reached volitional exhaustion and could not continue the test. Time to exhaustion was similar across all subjects (18.0 ± 1.0 minutes). This is important when monitoring physiological responses to a simulation to ensure that they are a product of the activity patterns only and not a result of different levels of fitness.

It is clear from the literature that simulations do offer a viable option for assessing the physiological demands of, and the effects of intervention strategies on, intermittent sport performance while maintaining a controlled and replicable situation. Examination of various simulations from intermittent sports indicates that a netball simulation should be designed from time motion analysis data representing the average game, that it should include other high intensity movement patterns that just sprinting and that it may be pertinent to refrain from including ball based activities since these only make up a small proportion of one player's game time. The relative success of many of previous intermittent sport simulations suggests that a similar approach can be applied to netball, opening up the possibility of further scientific investigation of the game as a whole.

2.5 Reliability & Validity

Reliability is the extent to which a variable can be repeatedly measured in a consistent manner (Fallowfield et al., 2005). If a test is not reliable then it cannot be considered valid (Thomas & Nelson, 2001). It will be important to establish whether the NIAT is reliable before assessing validity. If the NIAT was performed on two separate occasions, controlling for all other variables, we would expect to see the same results for %HR_{max}, sprint time, jump height and circuit time on each occasion. Delivering similar measurements when the test is repeated at a different time is known as test-retest reliability (Gratton & Jones, 2004). The test-retest reliability of the NIAT will be assessed by having all subjects perform the simulation on two occasions. Statistical analysis will be carried out on data collected from the two trials to establish if the test is repeatable.

In its most basic form validity is a measure of whether a test is measuring what it is supposed to measure (Thomas & Nelson, 2001; Gratton & Jones, 2004; Fallowfield et al., 2005). Basically, is the NIAT actually measuring or displaying the activity patterns and physiological demands of a netball game? However, validity is not quite as simple and there are several different forms of the measure. It is important to know exactly which form you are most interested in before attempting to test for it. Criterion validity refers to the degree in which results relate to a recognized criterion value. One type of criterion validity is concurrent validity in which a measuring instrument is administered concurrently or at about the same time (Thomas & Nelson, 2001). In the current study it

is concurrent validity that is being examined since %HRmax during the test is being compared to the measured physiological strain criterion value of %HRmax during match play at the same time during the season/year. Therefore, if the NIAT %HRmax scores show a good level of validity compared to those from match play it can be said that the NIAT has good criterion validity.

2.6 Summary

Research examining the physiological demands of intermittent sports is readily available, although relatively little of it relates to netball. It would appear that netball has some similarities to the profiles observed in sports such as rugby, soccer and hockey. However, additional constraints in player movement result in specific netball movement patterns and clearer positional differences in physiological data. Time motion analysis data give a clear picture of the movement and activity patterns of netball players, although to gain a clearer understanding of the physiological strain experienced during a game it is necessary to obtain a complete data set for the full range of positions in a netball team, the results of which may also be used to examine the criterion validity of a designed simulation. For this reason the heart rate profiles of senior netball players will be collected in the current study to examine positional patterns in match intensity, and to compare this match intensity data to simulation intensity data.

Simulations of match-activity create a repeatable and controlled method of assessing the efficacy of intervention trials on intermittent sport profiles. Previous simulations

designed for other intermittent sports have proven reliable and valid and have since been used to investigate their particular sport further. However, due to the discrete physiological demands placed upon netball players during a game, along with consideration of the positional variations, it would appear necessary to develop a simulation based solely around netball activity data in order to assess the benefits of selected ergogenic, nutritional and training variables on netball match performance. Therefore, time motion analysis data from previous research (Steele & Chad, 1991) will be used to design a simulation that replicates netball movement patterns and activity intensities. The simulation will be performed on two separate occasions to assess for reliability.

2.6.1 Assumptions of the study

The following assumptions were made in the present investigation:

- i. Similar fitness levels were maintained by individual subjects during the study.
- ii. Subjects followed similar hydration, nutritional and training patterns prior to the collection of both match and NIAT data.
- iii. Subjects were sufficiently familiarized with the NIAT protocol during the investigation to negate any learning effects between trials.
- iv. Heart rate was an indicator of the physiological demands of activity only.

CHAPTER III

METHODOLOGY

3.1 Introduction

The study was completed over two netball seasons (each of four months in length) and consisted of three parts:

- ◇ Preliminary measurements (including familiarisation)
- ◇ Game Data
- ◇ Netball Intermittent Activity Test (NIAT) Main trials.

3.2 Subject Characteristics

Eleven female club netball players participated in the study, which received approval from the Massey University Human Ethics Committee. All players were regular participants in a regional Premier Club competition and were training habitually. Participants were recruited during visits to training sessions. All data were gathered during the competition phase of the season. Details of the study were outlined to participants (Appendix A) who then signed a statement of informed consent (Appendix B) and completed a health questionnaire (Appendix C) prior to beginning the investigation.

3.3 Preliminary Measurements

A number of preliminary measurements were recorded during the familiarisation trials.

3.3.1 Physical Characteristics

Body mass (69.3 ± 5.3 kg), height (173.3 ± 5.5 cm) and age (21.4 ± 3.1 years) were recorded. Clothed body mass was measured to the nearest 0.1 kg using a set of digital scales (UC-321, A&D Co. Ltd., Tokyo, Japan). Height was recorded to the nearest 0.1 cm using a stadiometer (26SM, Surgical & Medical Products).

3.3.2 Maximal Oxygen Uptake ($\dot{V}O_{2max}$) & Maximum Heart Rate (HR_{max})

Participants performed a Multistage Fitness Test (Ramsbottom et al., 1988) in order to estimate maximal oxygen uptake. The procedure was fully explained to the participants on arrival at the testing venue, following which a standardised five minute jogging and stretching warm-up was performed. Participants wore a coded heart rate monitor (Polar S610i, Polar, Finland) for the duration of the test. Verbal encouragement was provided throughout completion of the Multistage Fitness Test.

The Multistage Fitness Test consisted of shuttle runs across a distance of 20 m, with the running speed being dictated by audible (“beep”) signals from a pre-recorded compact disc. Running speed was $2.22 \text{ m}\cdot\text{s}^{-1}$ initially and increased progressively by approximately $0.14 \text{ m}\cdot\text{s}^{-1}$ every minute. The test required participants to place one foot on or over the 20-m marked line, failure to do so resulted in a warning. Participants continued performing the required shuttle pattern until volitional exhaustion or failure to

adhere to the shuttle pattern resulted in them being withdrawn from the test. The level and shuttle number reached were recorded (Appendix) and a conversion table was used to estimate $\dot{V}O_{2\max}$ (Ramsbottom et al., 1988). The highest heart rate reached during the test was recorded as a subject's individual HR_{\max} .

3.4 Game Data

Participants were required to wear a coded heart rate monitor with data storage (Polar Team System, Polar, Finland) during Premier Club competition. The nature of the coded heart rate monitors allowed for accurate data collection within the rules of the game. It was initially intended to collect blood lactate concentration data during match play. However, consultation with the coaches and umpires involved resulted in the logistics of this being questioned and the collection of such data was not permitted. The games consisted of four 15 minute quarters, with three minute breaks at quarter times and a five minute break at half time. Games were played at the same indoor venue, on the same night of the week during the season and were played at either 6.45 pm or 8.15 pm. Data were collected until at least two full games were recorded for each subject. Player position was noted during the games, and the participants performed their team warm-up as they usually would during a competition match.

3.5 Netball Intermittent Activity Test (NIAT)

Previous time-motion analysis data (Steele & Chad, 1991) were used to develop an intermittent activity protocol that replicated movement patterns seen in netball match play. The test was performed on a netball court, and consisted of a circuit made up of different activity patterns (Figures 3.1 and 3.2). Participants had 130 seconds to complete this circuit, with the pace of each activity pattern being self-selected. If the circuit was completed within 130 seconds, participants were encouraged to undertake a short active recovery before assuming position to re-start the circuit. The circuit was performed seven times to represent a 15-minute quarter, and then performed four times to represent a whole game. Quarter breaks consisted of three minutes, while half time consisted of five minutes break. Performance data recorded during the test consisted of five metre sprint speed, vertical jump height and total time taken for each circuit.

Positional variations in the test were distinguished by the activity pattern during the skill circuit section of the protocol. These patterns are described in Table 3.1.

3.5.1 Familiarisation

Participants were allowed to familiarise themselves with the NIAT protocol by attending a preliminary trial where they performed one 15-minute block of the NIAT. During this trial they wore a coded heart rate monitor (Polar S610i) and were also given the opportunity to become accustomed to the other data-gathering methods used during the protocol such as the vertical jump and 5-metre sprint.

Table 3.1. Activity patterns during skill section of the NIAT protocol by positional variation.

| <i>Positional Group</i> | <i>Activity between cones</i> | <i>Activity at front cones</i> | <i>Activity at back cones</i> |
|-------------------------|-----------------------------------|------------------------------------|-----------------------------------|
| Circle Defence (D) | Shuffle | Defend shot | Jump |
| Centre Court (C) | Shuffle | Jump | Jump |
| Circle Attack (A) | Shuffle | Shoot | Jump |

3.5.2 Main trials

Participants performed two main trials of the NIAT, separated by a minimum of five days. Each trial was performed in the evening at a similar time to when the match data was collected.

A 30-minute standardised warm up consisting of jogging, footwork patterns, stretching and ball drills was performed before each trial, replicating the warm-up usually performed before competition games (see Appendix D for schematic of standard warm up). Participants were requested to follow the same pattern of food and drink consumption and physical activity pattern prior to all matches and NIAT trials.

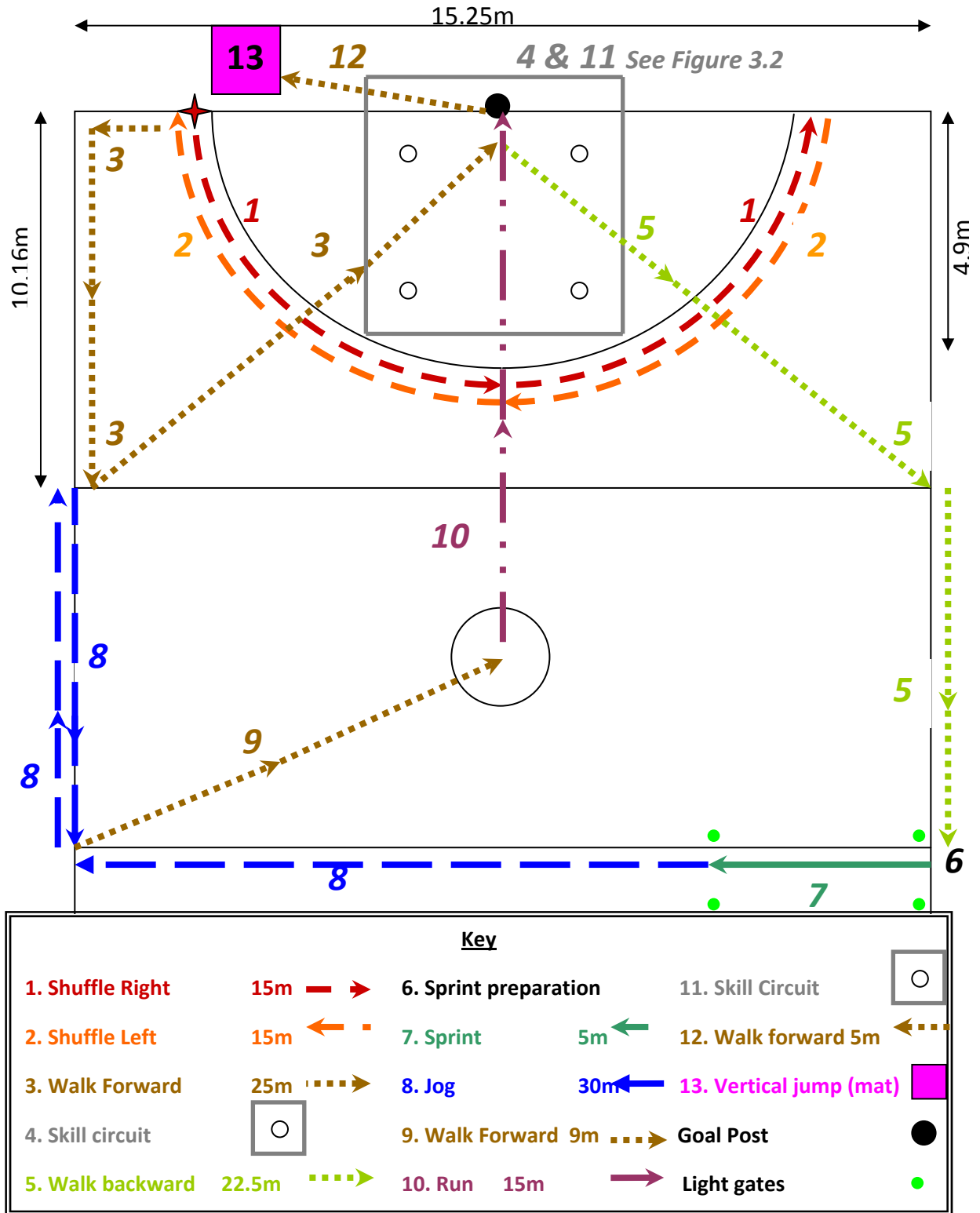


Figure 3.1. Diagrammatical representation of the NIAT

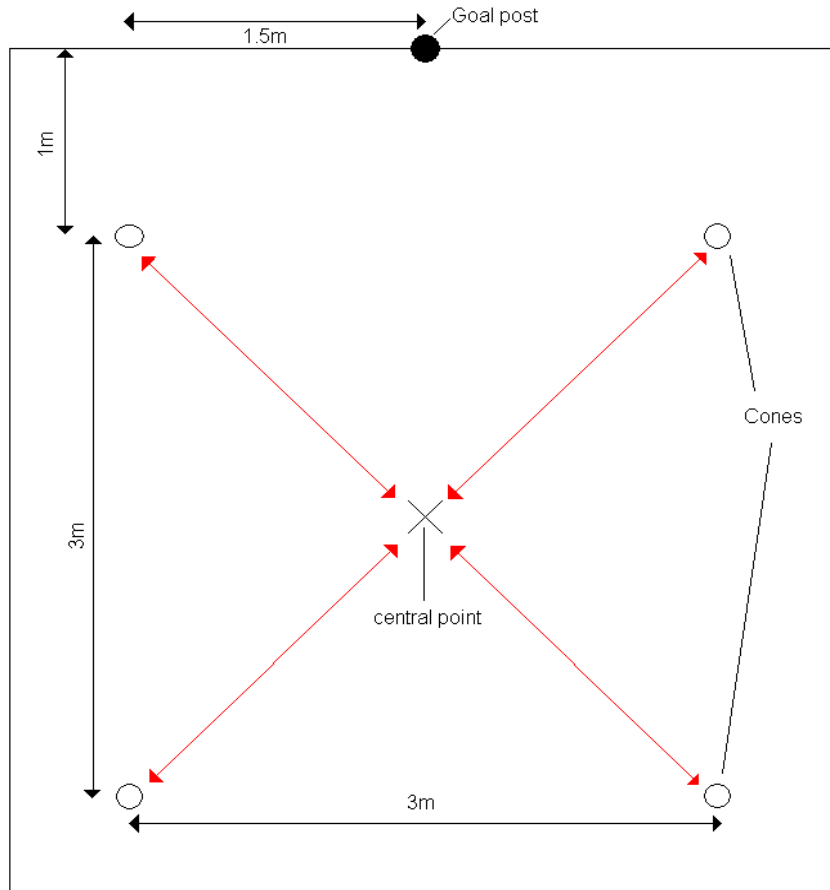


Figure 3.2. Diagrammatic representation of the skill circuit within the NIAT. *(Participants begin at the central point, shuffle out along the red lines to one of the four cones, perform a skill and then shuffle back to the central point).*

Four blocks of 15-min of the NIAT were performed during each trial to match the time spent playing during competition games. Participants wore coded heart rate monitors (Polar S610i, Polar, Finland) programmed to record heart rate every five seconds. Sprint speed over five metres was recorded using wireless timing gates (Brower Speedtrap 2, USA), vertical jump height was recorded using a jump mat (Speedlight, Australia), and total circuit time was recorded with a digital clock (Electronic 870A, China). Verbal encouragement was given during the sprint and jumping activities in order to induce

maximal effort although participants were not given any feedback about their results until after they had completed the trial. Fluid intake was limited to quarter breaks and was ad libitum (as per match conditions).



Figure 3.3. Participant completing skill circuit during NIAT (Centre positional variation).

3.6 Facilities

All data were collected in indoor facilities. Match heart rates were recorded during the Premier Club Competition games at North Shore Events Centre, while familiarisation, multi-stage fitness test, and NIAT trials were performed at Massey University Recreation Centre sports hall. Both have surfaces that are non-slip, wooden sprung floors with standard netball court dimension markings. Ambient temperature and relative humidity were not controlled for but were measured using a standard wireless weather station (DSE Z111, China) (Mean \pm standard deviation; match temperature 18.3 ± 0.8 °C; relative humidity 49.2 ± 4.4 %; NIAT temperature 18.4 ± 1.0 °C; relative humidity 45.1 ± 6.1 %).

3.7 Statistical Analysis

All data were tested for parametric assumptions of normality (Kolmogorov-Smirnov) and homogeneity of variance (Levene's test) at $p < 0.05$.

Match data for mean %HR_{max} was grouped in three different ways and each analysed separately. Firstly, mean %HR_{max} for all players was separated into four playing quarters (1st, 2nd, 3rd, and 4th), which were all compared with each other to give an indication of any changes in match intensity over the duration of the game. Mean %HR_{max} for the whole game was then compared between positional groups (Defences $n = 3$, Wings $n = 3$, Centres $n = 2$, and Attacks $n = 3$) to examine if match intensity data supported previously identified positional groupings. The analysis on heart rate data during match play grouped across four playing quarters (Q1 $D(10) = 0.14$, *ns*; Q2 $D(10) = 0.18$, *ns*; Q3 $D(11) = 0.18$, *ns*; Q4 $D(11) = 0.18$, *ns*; equal variances $F(3, 38) = 0.43$, *ns*) and across four positional groups (D $D(12) = 0.12$, *ns*; W $D(12) = 0.14$, *ns*; C $D(8) = 0.19$, *ns*; A $D(10) = 0.15$, *ns*; equal variances $F(3, 38) = 0.71$, *ns*) indicated positive assumptions of normality and homogeneity of variance ($p > 0.05$). Therefore, two-way analysis of variance (ANOVA) with playing quarter and positional group as fixed factors was used to determine differences in heart rate data during match play. Bonferroni tests were performed post-hoc to determine where any differences lay. The intensity data for match play was also examined further by looking at time spent in heart rate zone for each positional group. Time in heart rate zone for positional groups violated assumptions of normality and homogeneity ($p < 0.05$). Analysis was carried out using Kruskal-Wallis non-parametric test, with post-hoc Mann-Whitney U tests to determine any differences in

intensity between the four positional groups. At this stage null hypothesis H01 was rejected or accepted depending on the outcome of the analysis.

Data for mean %HR_{max} during the game was compared to mean %HR_{max} during the NIAT to examine the criterion validity of the NIAT. Positional groupings in this section of the analysis depended upon the outcome of the previous analysis of mean %HR_{max} during match play. This indicated that positional grouping for the NIAT should reflect the similarity in exercise intensity between the C and W group, so that these combine to form one Centre Court group (CC, n = 5), and thus three groups in total. Heart rate data for condition (NIAT vs. Match) was found to violate the assumption of normality and homogeneity, specifically %HR_{max} for the Defence group in NIAT ($D(24) = 0.351$, $p < 0.05$) and unequal variance was found within the %HR_{max} NIAT data set ($F(2,85) = 8.721$, $p < 0.05$). Therefore, heart rate for condition data were analysed using Wilcoxin signed ranks test. At this stage null hypothesis H02 was rejected or accepted depending on the outcome of the analysis.

Subject characteristic data for estimated $\dot{V}O_{2max}$ and HR_{max} between positional groups violated assumptions of normality and homogeneity ($p < 0.05$) and so were analysed using Kruskal-Wallis non-parametric tests, with post-hoc Mann-Whitney U tests.

Test-retest validity was assessed for the NIAT by comparing sprint times, jump height, circuit times and mean %HR_{max} between NIAT1 and NIAT2. These parameters were also examined over the duration of both NIAT trials in order to examine for effects of fatigue. All data collected during the NIAT trials and grouped according to trial were shown to be normal and homogenous ($p > 0.05$) and so two-way analysis of variance (ANOVA) with repeated measures was applied to protocol data to determine any differences between trials (NIAT1 vs. NIAT2). Pearson's correlation (r) and intra-class correlation coefficients (ICC) were used to assess reliability between sets of scores. The method chosen to calculate ICC was the "two-way random" method, as suggested by Atkinson and Nevill (1998), using SPSS (version 16.0). The standard error of measurement (SEM) was also used to assess test-retest reliability using the most common method of $SEM = s\sqrt{1 - ICC}$ (Atkinson & Nevil, 1998). The SEM covers only 68% of the population (s standard deviation (s)) and so to make it applicable to 95% of the population (i.e. $1.96 s$), the 95% confidence intervals (95% CI) were calculated by multiplying the SEM by 2. The coefficient of variation (CV) was used as a further method to assess reliability of the NIAT data by dividing the standard deviation by the mean and multiplying by 100. The final method of assessing repeatability was the "95% absolute levels of agreement" (LOA) as proposed by Bland and Altman (1986). The methods used to assess reliability are similar to those used to assess the reliability of soccer skill tests (Ali et al., 2007b). At this stage null hypotheses H03 and H04 were rejected or accepted depending on the outcome of the analysis. The null hypotheses were rejected at an alpha level of $p < 0.05$ unless otherwise stated.

CHAPTER IV

RESULTS

4.1 Match Data

4.1.1 Playing Quarter

There was a significant main effect of game quarter on %HR_{max} during match play ($F(3, 26) = 3.42, p < 0.05, \omega^2 = 0.03$). Post-hoc tests revealed a difference in %HR_{max} between Quarters 1 and 3, and 1 and 4 respectively. However, these differences were not significant at the alpha level (Quarter 1 vs. Quarter 3 $p = 0.053$; Quarter 1 vs. Quarter 4 $p = 0.053$) (Figure 4.1). Further analysis of %HR_{max} between match halves using two-way analysis of variance (ANOVA) with playing half and positional group as fixed factors revealed a significantly lower %HR_{max} in the second half of match play compared to the first $F(1, 13) = 6.65, p < 0.05, \omega^2 = 0.005$ (Figure 4.2).

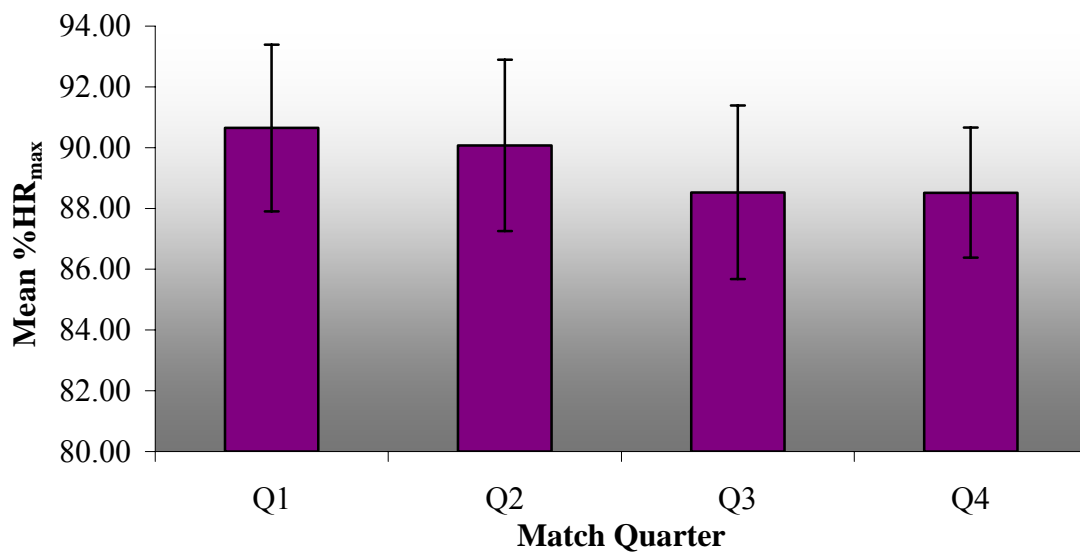


Figure 4.1 Mean (\pm SD) % HR_{max} for the four quarters of match play.

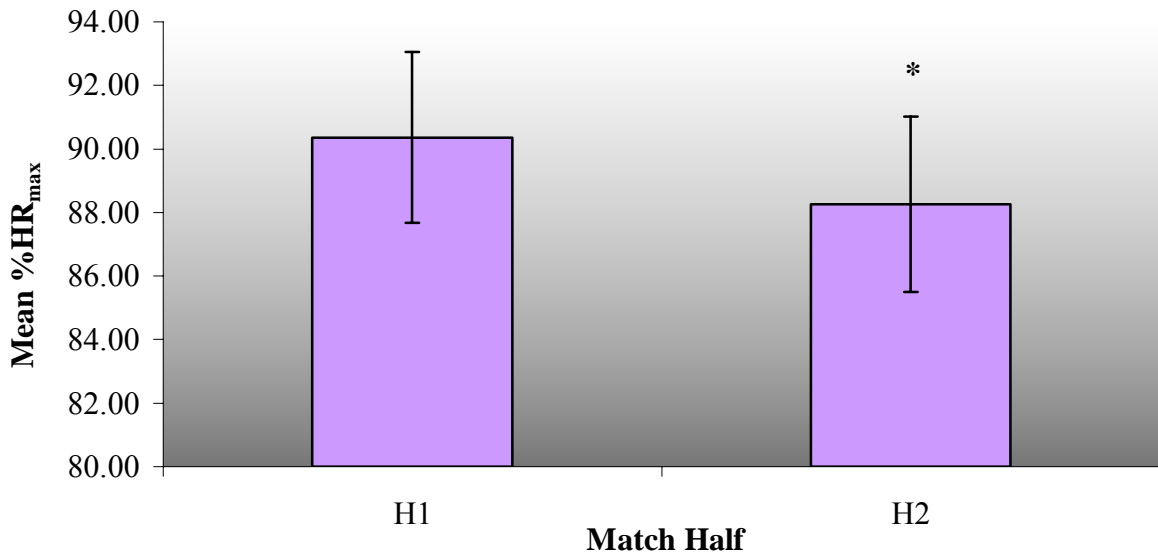


Figure 4.2 Comparison of match %HR_{max} between halves (mean ± SD).

* Significantly different from H1 (p<0.05)

4.1.2 Positional Group

There were no significant differences between positional groups for $\dot{V}O_{2max}$ (H(2) = 5.07, p>0.05) and HR_{max} (H(2) = 1.20, p>0.05); (Table 4.1).

Table 4.1 Median $\dot{V}O_{2max}$ and HR_{max} values by positional group.

| Positional Group | Median $\dot{V}O_{2max}$ (ml·kg ⁻¹ ·min ⁻¹) | Median HR _{max} (beats·min ⁻¹) |
|------------------|---|--|
| Defence (n=3) | 45.6 | 196.0 |
| Wings (n=3) | 51.3 | 199.5 |
| Centres (n=2) | 51.2 | 202.0 |
| Attacks (n=3) | 48.4 | 194.0 |

There was a significant main effect of playing position on %HR_{max} during match play $F(3, 26) = 20.25, p < 0.001, \omega^2 = 0.63$. Post hoc t-test revealed that %HR_{max} for Defence players was significantly higher during the game than all other positions ($p < 0.005$), and %HR_{max} for Centres was significantly higher than Attack players ($p < 0.005$) (Figure 4.3).

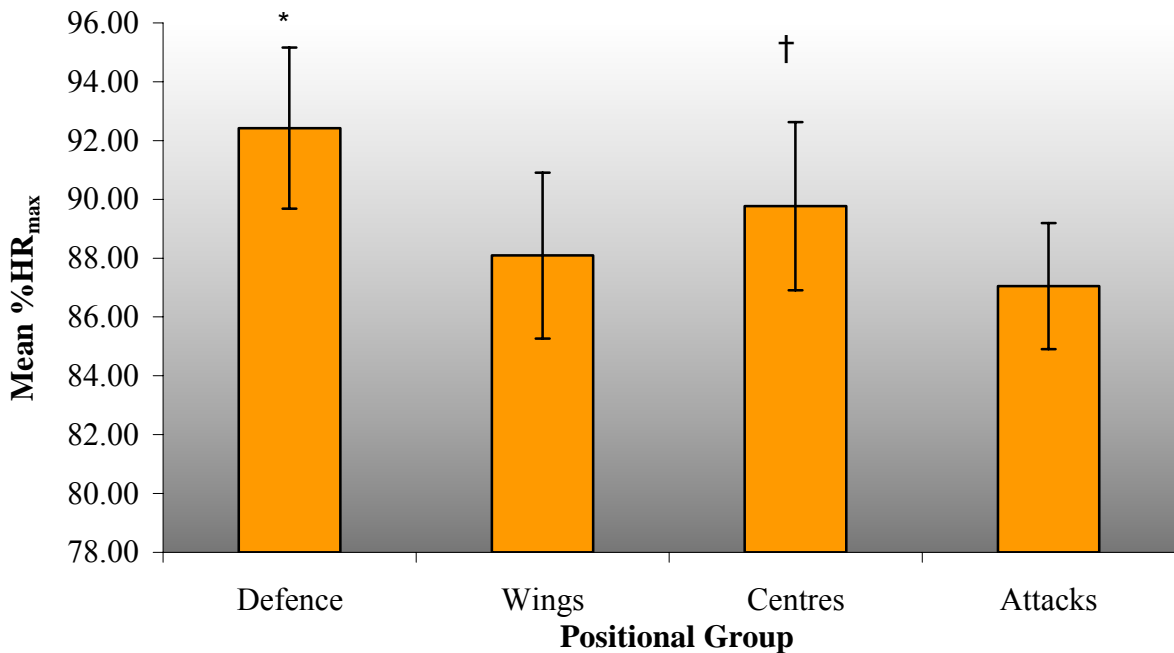


Figure 4.3 Mean (\pm SD) %HR_{max} during match play for the different positional groups.

* Significantly different from all other positional groups ($p < 0.005$)

† Significantly different from Attack ($P < 0.005$)

There was no significant difference between percent of total game time (%time) spent in HR Zones 1, 2 and 4 between positional groups (heart rate zones are defined in Table 2.1). The non-parametric tests revealed a significant difference between positional groups for %time in Zone 3 ($H(3) = 7.227, p < 0.05$). Mann-Whitney tests were used post-

hoc, looking at differences between Attacks and all other positions. A Bonferroni correction was applied and so all effects are reported at a 0.0167 level of significance. It appeared that %time in Zone 3 was no different between Attacks and Defence ($U = 0$, $r = -0.80$), Attacks and Wings ($U = 0$, $r = -0.80$), and Attacks and Centres ($U = 0$, $r = -0.77$). Results are illustrated in Figure 4.4.

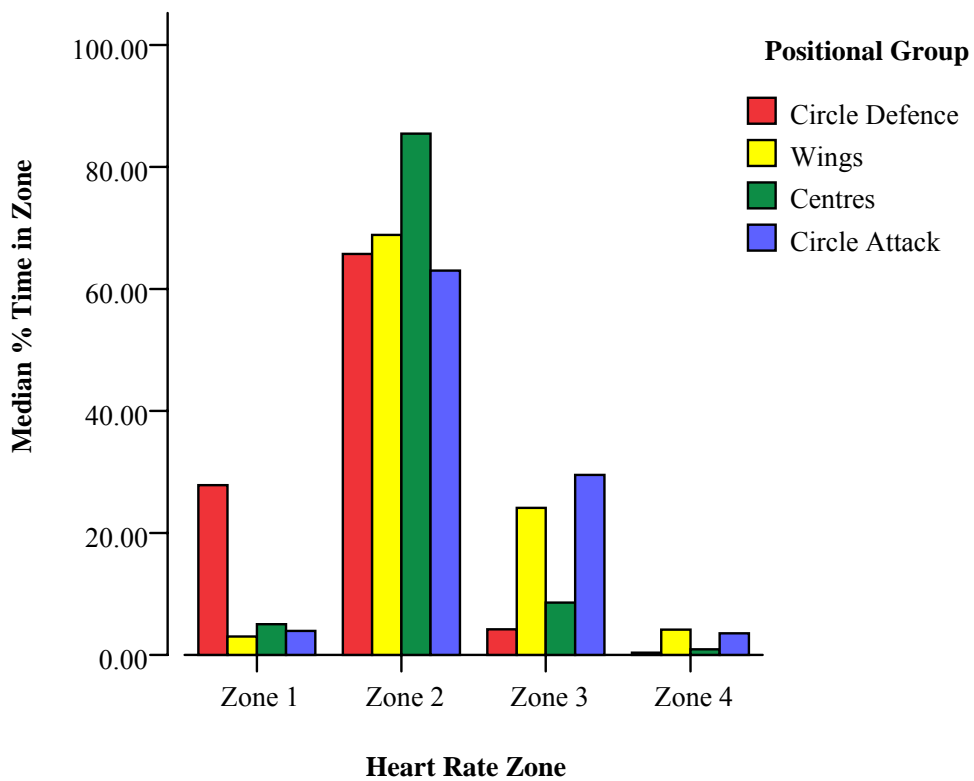


Figure 4.4 Median % time in Heart Rate Zone by positional group.

4.2 NIAT Criterion Validity

For the Defence group %HR_{max} was not significantly different between match play (*Mdn* = 92.52%) and NIAT (*Mdn* = 86.27%), $T = 0$, $p > 0.05$. For Centre Court players, %HR_{max} was significantly higher during match play (*Mdn* = 89.70%) than during NIAT (*Mdn* = 79.70%; $T = 0$, $p < 0.05$, $r = -0.91$). For the Attack group %HR_{max} was not significantly different between match play (*Mdn* = 86.95%) and NIAT (*Mdn* = 82.93%; $T = 0$, $p > 0.05$) (Figure 4.5).

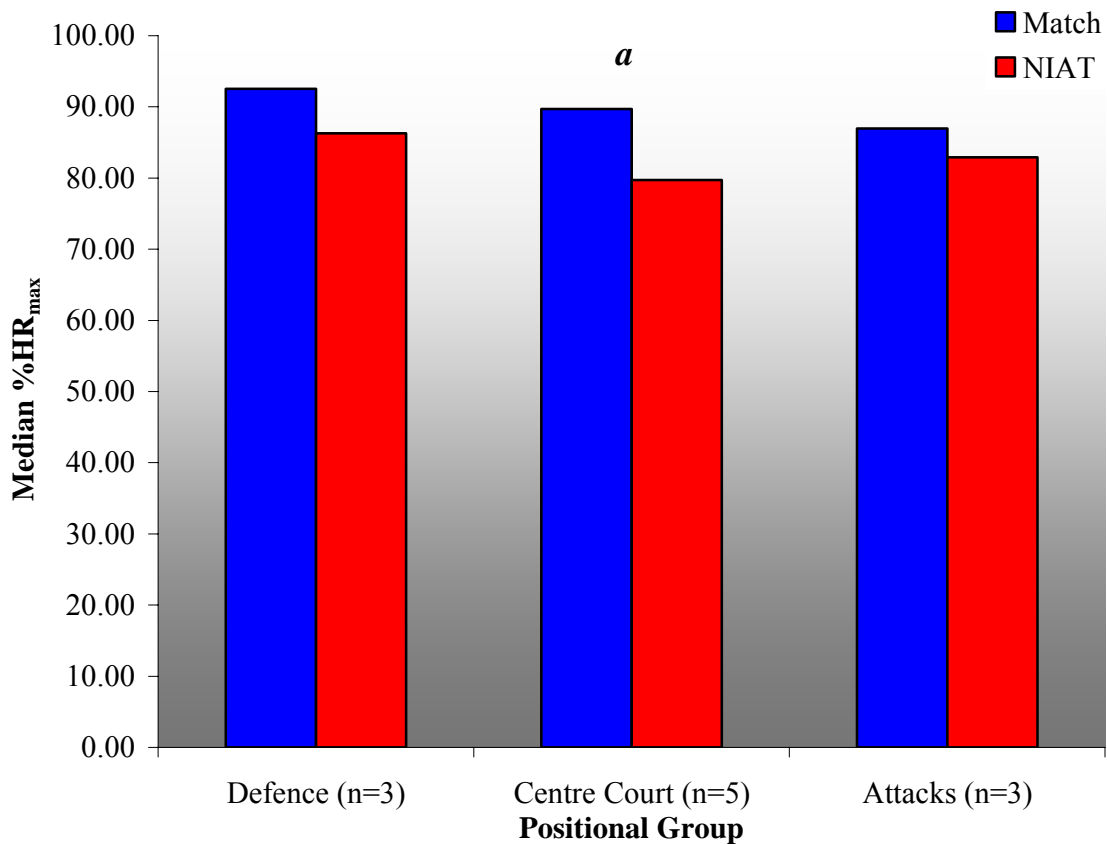


Figure 4.5 Median % HRmax for Positional Groups in Match and NIAT.

a Significantly higher than protocol ($p < 0.05$)

4.3 NIAT Reliability

4.3.1 Sprint Time

There was no significant difference in sprint data between NIAT trials ($F(1, 10) = 1.39$, $p > 0.05$) (Table 4.2). There was also no significant difference in sprint data between quarters of NIAT trial, $F(3, 30) = 1.52$, $p > 0.05$. Furthermore, there was no significant interaction between NIAT trial and quarter for sprint data, $F(3, 30) = 1.27$, $p > 0.05$. There was a moderate correlation between trials for 5 m sprint time ($r = 0.66$, $p < 0.001$; Table 4.3). The ICC for sprint time, although calculated differently, shows an identical result as the Pearson's correlation (Table 4.3). The SEM and 95% CI for sprint time were low (0.03 and 0.07s respectively) indicating reliability of this aspect of the NIAT. The CV for sprint time was acceptable (4.8%) (Table 4.3). The LOA for 5 m sprint time (Table 4.4) indicated a small amount of random error (± 0.10 s).

4.3.2 Jump Height

There was no significant difference in jump height data between NIAT trials, $F(1, 10) = 0.38$, $p > 0.05$ (Table 4.2). There was also no significant difference in jump height data between quarters of NIAT trial, $F(3, 30) = 0.23$, $p > 0.05$. Further, there was no significant interaction between NIAT trial and quarter for jump data, $F(3, 30) = 0.79$, $p > 0.05$. There was a good correlation between trials for vertical jump height ($r = 0.91$, $p < 0.001$). The ICC for vertical jump height shows a nearly identical result as the Pearson's correlation. The SEM and 95% CI for jump height were low (1.23 and 2.46 cm) indicating reliability of this aspect of the NIAT. The CV for jump height was over 10% (13.4%) indicating that there may have been some variance in jump height between

the two trials. The LOA for jump height indicated a moderate amount of random error (± 3.43 cm).

Table 4.2 Mean NIAT performance times (\pm standard deviations)

| | NIAT 1 | NIAT2 | Mean |
|----------------------------------|-----------------------|-----------------------|-----------------------|
| 5m sprint time (s) | 1.27 (± 0.06) | 1.25 (± 0.06) | 1.26 (± 0.06) |
| Vertical jump height (cm) | 29.12 (± 4.17) | 28.82 (± 3.60) | 28.97 (± 3.87) |
| Circuit time (s) | 107.49 (± 3.22) | 107.89 (± 4.27) | 107.69 (± 3.77) |
| %HR_{max} | 82.56 (± 4.66) | 81.03 (± 4.13) | 81.80 (± 4.50) |

4.3.3 Circuit Time

Mauchly's test indicated that the assumption of sphericity had been violated for the main effect of quarter, $\chi^2 (5) = 19.34$, $p < 0.05$, and for the interaction of trial and quarter, $\chi^2 (5) = 16.08$, $p < 0.05$. Therefore, degrees of freedom were corrected using the Greenhouse-Geisser estimates of sphericity ($\epsilon = 0.45$ for the main effect of quarter, and 0.68 for the main interaction effect of trial and quarter). There was no significant difference in circuit time between NIAT trials, $F (1, 10) = 0.33$, $p > 0.05$ (Table 4.2). There was also no significant difference in circuit time between quarters of NIAT, $F (1.34, 13.35) = 1.49$, $p > 0.05$. Further, there was no significant interaction between NIAT trial and quarter for circuit time, $F (2.04, 20.44) = 2.06$, $p > 0.05$. There was a moderate correlation between trials for circuit time ($r = 0.72$, $p < 0.001$). The ICC for circuit time shows a nearly

identical result as the Pearson's correlation. The SEM and 95% CI for circuit time were low (2.08 and 4.16 s) indicating reliability for this aspect of the NIAT. The CV for circuit time was acceptable (3.5%). The LOA for circuit time indicated a small amount of random error (± 5.80 s).

4.3.4 Percent Heart Rate Maximum (%HR_{max})

Mauchly's test indicated that the assumption of sphericity had been violated for the main effect of quarter, $\chi^2(5) = 23.14$, $p < 0.01$. Therefore, degrees of freedom were corrected using the Greenhouse-Geisser estimates of sphericity ($\epsilon = 0.43$). There was no significant difference in %HR_{max} between NIAT trials, $F(1, 10) = 4.19$, $p > 0.05$ (Table 4.2). There was also no significant difference in %HR_{max} between quarters of NIAT, $F(1.29, 12.94) = 2.06$, $p > 0.05$. There was a significant interaction effect between quarter and NIAT, $F(3, 30) = 3.60$, $p < 0.05$. This indicates %HR_{max} was different between quarters depending on which trial was observed. To break down this interaction, contrasts were calculated comparing NIAT trials and all quarters to the first quarter. This revealed a significant interaction when comparing 1st Quarter to 4th Quarter for NIAT1 compared to NIAT2, $F(1, 10) = 6.78$, $r = 0.64$. Looking at the interaction graphs these reflect that the decrease in %HR_{max} from NIAT1 to NIAT2 is not as large in 4th Quarter as it is in 1st Quarter. The remaining contrasts revealed no significant interaction term when comparing Quarters between Trial 1 and Trial 2. There was a good correlation between trials for %HR_{max} ($r = 0.82$, $p < 0.001$). The ICC for %HR_{max} shows a nearly identical result as the Pearson's correlation. The SEM and 95% CI for %HR_{max} were low (1.95 and 3.90%) indicating reliability for this aspect of the NIAT. The CV for %HR_{max} was

acceptable (5.5%). The LOA for %HR_{max} indicated a small amount of random error (\pm 5.35%).

Table 4.3 Pearson's correlation (*r*), intra-class correlation coefficients (ICC), standard error of measurement (SEM), 95% confidence intervals (95% CI), and coefficient of variation (CV) for NIAT performance.

| Variable | <i>r</i> | ICC | SEM | 95% CI | CV (%) |
|-----------------------------|-----------------|------------|-----------------|-----------------|---------------|
| 5m sprint time | 0.66 | 0.66 | \pm 0.03 (s) | \pm 0.07 (s) | 4.76 |
| Vertical jump height | 0.91 | 0.90 | \pm 1.23 (cm) | \pm 2.46 (cm) | 13.36 |
| Circuit time | 0.72 | 0.70 | \pm 2.08 (s) | \pm 4.16 (s) | 3.50 |
| %HR_{max} | 0.82 | 0.81 | \pm 1.95% | \pm 3.90% | 5.50 |

Table 4.4 Absolute limits of agreement (LOA) for NIAT performance.

| Variable | LOA |
|-----------------------------|--|
| | (Mean bias \pm 1.96 s) |
| 5m sprint time | 0.02 \pm 0.10 (s) |
| Vertical jump height | 0.30 \pm 3.43 (cm) |
| Circuit time | -0.40 \pm 5.80 (s) |
| %HR_{max} | 1.53 \pm 5.35 (%) |

CHAPTER V

DISCUSSION

The aim of the current study was to design a reliable Netball simulation that closely resembled the physiological strain experienced during an actual netball match. Heart rate data collected during match play indicated the need for three different positional variations of the NIAT according to the different intensities experienced during the game; one for Defence players, one for Centre Court players (combination of Wings and Centres) and one for Attack players. The NIAT was then designed using previous time motion analysis data (Steele & Chad, 1991), and heart rate data recorded during the NIAT was compared to those taken in match play to determine criterion validity. In the current population the NIAT showed good criterion validity for Defence and Attack players, but not Centre Court. However, results indicate that the NIAT is reliable.

5.1 Match Data

The current study indicated an overall mean (\pm SD) %HR_{max} for all subjects during match play of 89.6 (\pm 3.4) %. There are currently no other studies in the sport science literature that report data for mean %HR_{max} in netball match-play for comparison, although the value in the current study is close to that observed in male elite basketball of 87.0 \pm 2% (McInnes et al., 1995), reflecting the similarities in game activities between netball and basketball. Mean %HR_{max} in the current study is similar to values shown in female soccer (87.0%; Krstrup et al., 2005), but the values for both female populations are

higher than those shown in male soccer (82.5%; Edwards & Clark, 2006), male singles tennis (81.0%; Christmass et al., 1998; Smekal et al., 1998), and male rugby league (84.3%; Coutts et al., 2003). It may be that female athletes are predisposed to exhibiting higher heart rates as a proportion of their maximum during intermittent sports than their male counterparts. One explanation for this is that in males a greater quantity of blood can be carried to the working muscle, resulting in female participants having to increase their heart rate further than males to adequately supply the muscle under similar exercise intensities (Shephard, 2000). The latter author also recognises a greater rise of core temperature in females than in males at similar exercise intensities, resulting in higher heart rate responses in women.

Some authors have recognised the limitations to using heart rate data during intermittent exercise due to the fact that it does not immediately reflect exercise intensity variations (Christmass et al., 1998). In the current study variations in heart rate occurred during the course of the game as a reflection of the intermittent nature of activity. However, heart rate can give an illustration of mean exercise intensity, and therefore a useful index of overall physiological strain (Christmass et al., 1998; Coutts et al., 2003), and has been shown to be a feasible means of estimating energy expenditure in elite hockey (Boyle et al., 1994). The average exercise intensity in the current study indicates a high level of aerobic loading, although other sports with similar intensity patterns have indicated that a combination of anaerobic and aerobic energy production is required in order to perform high intensity exercise in short bursts, whilst recovering adequately from these bursts to maintain performance over the entire match (Allen, 1989; Liddle et al., 1996). Otago

(1983) recognised that netball players require a good level of aerobic fitness in order to aid in recovery during the intermittent high intensity nature of the game.

5.1.1 Playing Quarter

The current investigation indicated that there was a significant difference in %HR_{max} between playing quarters of the total game, although statistical analyses was unable to reveal the exact location of this difference at the alpha level ($p < 0.05$). The statistical analyses and graphical representation of the results does indicate some tendency for %HR_{max} to decline over the duration of the game, with a statistically non-significant difference between the first quarter and third and fourth quarters. Further analysis of the heart rate data, comparing halves instead of quarters, revealed a significantly higher %HR_{max} in the first half ($90.36 \pm 2.69\%$) of match play compared to the second half ($88.26 \pm 2.76\%$; $p < 0.05$). This trend is supported by studies indicating that heart rate values decrease over the course of a soccer game, with first half values often being significantly higher than second half values (Ali & Farrally, 1991; Edwards & Clark, 2006). Activity data focused on soccer appears to confirm findings from heart rate studies since total distance covered, distance covered at high intensity and time spent performing high intensity running have been found to decrease both towards the end of a 45-minute half, and in the second half of a 90-minute game (Mohr et al., 2003; Krstrup et al., 2005; Rampini et al., 2007b), although one study found no significant reductions in high intensity exercise performance over time (Bangsbo, 1994) When the activity pattern is kept constant over time (as in the current study with the NIAT), there appears to be no significant temporal effect on heart rate (since %HR_{max} was not different between the four quarters of the NIAT). This suggests that during netball match play, the pattern of

activity is reducing in intensity for some reason. Explanations offered for the pattern of reduced activity in other intermittent sports include the effects of fatigue resulting in less effort being contributed in the latter part of the game (Ali & Farrally, 1991; Rebelo et al., 1998; Krstrup et al., 2005), and the possibility that the result of the game may have an impact on the participant's work rate (Ali & Farally, 1991; Woolford & Angove, 1991). Lothian and Farrally (1994) found that there was significantly less time spent in high intensity activity in the second half of a women's hockey game compared to the first. They suggested that the score towards the end of the game may have been a factor in reducing the activity pattern of the players, but further analysis revealed that all players had lower work rates in the second half regardless of the score. Therefore, they concluded that the effects of fatigue contribute towards the reduced work rate in the second half of a game of hockey. The notion of score having an activity pattern outcome was further rejected by data from soccer where games that had a difference in score of more than one goal showed no systematic differences in activity patterns from closer matches (Mohr et al., 2003). The previous authors also suggested that fatigue occurs temporarily during a soccer game, leading to periods of reduced high-intensity exercise performance to allow for recovery.

The observed pattern in heart rate in the current study suggests that the effects of fatigue lead to a drop-off in activity intensity in the latter parts of the game, with data collected from participants completing full games (i.e. no substitutions) and games against a variety of standard of opposition (i.e. different results). Brief systematic analysis of netball activities by Barham and Wilson (1981) revealed some observations of reduced activity in

the last quarter of a game including a reduced frequency of jumping and passing the ball on the run, which may be indications of a lower activity level towards the end of a game similar to hockey and soccer. The intensity reduction notion in intermittent sports gains further support by the finding of a lack of significant difference in motion categories between first and second halves of elite male hockey games where unlimited substitutions serve to attenuate the effects of fatigue (Spencer et al., 2004). However, without the presence of time-motion analysis data in the current study a definitive conclusion about any reductions in exercise intensity during the game cannot be reached.

Edwards and Clark (2006) recognised that success in intermittent sports is related to a player's ability to sustain high intensities over the duration of the game. The current study indicates that fatigue could be a factor in netball in the latter stages of the game, resulting in a reduction in exercise intensity. In order to achieve success, therefore, it will be important for coaches to find a training method or ergogenic aid to assist in the maintenance of high intensity exercise over the duration of a netball game above that achieved by opposition players. The development of a valid and reliable simulation would provide a valuable tool for research into such methods and aids and as such adds further justification to the current research.

5.1.2 Positional Group

There were no significant differences between positional groups for parameters of aerobic fitness $\dot{V}O_{2\max}$ and HR_{\max} . This indicates that there should be little or no effects on heart

rate during the game due to fitness attributes and any differences in %HR_{max} between positions should be due to exercise intensity alone.

There was a significant main effect of playing position on %HR_{max} during match play with Defence players showing significantly higher %HR_{max} values to all other positions, and Centres showing significantly higher %HR_{max} values to Attack players. This indicates that Defence players worked at the highest intensity over the duration of the game and were significantly different from other positions on court in this respect. The other three groups had some similarities in the cardiac strain exhibited, and it appears that the Wing positions were similar to both Centres and Attacks. This would be expected since Wings are required to perform a similar skill set to Centres but play in a similar court area to Goal Attack. The higher intensity exercise exhibited by the Defensive group indicates that a separate simulation should be designed with this group in mind. Centre and Attack groups should also have simulations designed to meet their positional needs, and it was decided that Wings should be grouped with Centres due to the similar skill sets of the positional groups. This is a similar positional pattern to that already indicated in netball for other physiological variables in the literature (Bale & Hunt, 1986; Chad & Steele, 1991; Cooper et al., 2002), and also reflects previous time motion analysis data on netball match play (Steele & Chad, 1991).

In the early nineteen-nineties Woolford and Angove (1991; 1992) attempted to describe heart rate data during match play but only gave full data sets for four positions: WA, GA,

C and WD. Contrary to the present investigation these investigators found that it was the GA (a member of the Attack group) who exhibited the highest heart rates for the duration of the game. However, they did go on to recognise that the games analysed for the GA were three of the hardest games encountered in the competition and this may have served to positively skew the GA's heart rate data. The authors concluded that both the nature of the opposition and the activity pattern of the game serve to influence the intensity that the game is played at. In the current investigation the heart rate profiles were obtained from games with various end results: some close games, some convincing wins and some significant losses. In this way it is hoped that the current data set reflects the heart rate response to an average game of netball and gives a good idea of the positional variation in heart rate response.

Variations in activity and the intensity of that activity in intermittent sports such as soccer and hockey has been related to aerobic fitness, particularly in female subjects (Lothian & Farrally, 1994; Krstrup et al., 2005; Rampini et al., 2007a). These authors indicated that the ability to perform high intensity exercise over the duration of the game was related to the individual player's aerobic power. This may explain some of the differences in heart rate response in the current study. However, examination of participants' estimated maximal oxygen uptake results from the Multistage Fitness Test indicated no significant positional group differences in aerobic fitness. There did appear to be a slight but non-significant difference in the aerobic fitness of the Defence group from comparisons of $\dot{V}O_{2max}$, with subject number potentially negating any significant differences between positional groups. However, the difference did not appear to be large enough to create the

level of significance in heart rate response to match situations compared to the other positions, although it would be beneficial to strengthen this data set with more subjects in future research. It is more likely, therefore, that it is the activity pattern of Defence players that creates this higher physiological strain, with defensive activities being performed at higher intensities and for longer time periods. This is likely due to the nature of a Defensive player's movements, which are often not planned and are in response to those of the attacking player. It is also likely that many of these movements are high intensity ones such as sprinting and leaping to make an interception, and jumping to defend a shot at goal. This could, therefore, lead to a conclusion similar to that made in tennis in that physiologic responses are dependant upon the nature and character of the playing pattern rather than the subjects' physical ability (Smekal et al., 1998). It is suggested, therefore, that simulation models for the three positional groups should not adjust speeds of activity patterns according to the individual's aerobic power.

Time spent in prescribed heart rate zones in the current study indicated only a significant difference in the time spent in Zone 3 (75-85% HR_{max}) between positional groups. Post-hoc tests failed to identify the location of this significance due to the Bonferroni correction. However, observation of Figure 4.3 does indicate some non-significant trends in the data, which may have been significant had sample size in the present study been larger. It would appear that D spend more time in Zone 1 (95% HR_{max}), and it is likely that it is the time in this high-intensity heart rate zone that led to this group having a significantly higher average %HR_{max} than the other groups. It would also appear that C spent more time in Zone 2 (85-95% HR_{max}) than the other groups, which may account for

the C having a higher average %HR_{max} than the A group. Further, W and A appeared to spend more time in the lower intensity Zone 3 (75-85% HR_{max}) than the other two positional groups. It would appear, therefore, that W and A carry out less high-intensity activity and have more time for recovery, resulting in the average %HR_{max} for these two positional groups being lower than that for D and C.

The D players in the current study spend just under 30% of their match time in Zone 1. It has been suggested that durations of near maximal work such as this will require a large contribution from anaerobic pathways (Deutsch et al., 1998). It is also likely that lactate concentrations in the blood would be high for all positional groups, since lactate production usually exceeds elimination above approximately 75% HR_{max} (Woolford & Angove, 1992; Liddle et al., 1996). When lactate concentration is high there is a resultant decrease in the pH of the blood from the build up of H⁺ (McArdle et al., 2000; Powers & Howley, 2001). Both the acidosis and lactate itself have been shown to reduce muscle force by various mechanisms including impairment of excitation-contraction coupling (Favero et al., 1997; Metzger & Fitts, 1987) and decreasing Ca²⁺ release from the sarcoplasmic reticulum (Hill et al., 2001; Stackhouse et al., 2001). Acidosis may further induce fatigue by influencing pain receptors in the brain (Bogdanis et al., 1994) or by reducing key glycolytic enzyme activity (Krebs et al., 1959; Chasiotis et al., 1982). If lactate concentrations in the current population were high during match play, this would have contributed to the apparent significant drop off in exercise intensity during the second half of the game. However, this suggestion cannot be supported without the presence of blood lactate concentration measures, which were not included in the present

study due to procedural concerns by coaches and umpires. In order to more accurately assess the roles of specific energy systems within netball it would be suggested that any future study include such measures.

The lack of significance in %HR_{max} between quarters has led to only a partial rejection of null hypothesis H01: Mean %HR_{max} does not differ between quarter but does differ between positional groups during competition games in the present study. This could lead to creation of a revised null hypothesis H01(b): Mean %HR_{max} does not differ between match halves and positional groups during competition games, which would subsequently be rejected.

5.2 NIAT Validity

Results from the comparison of match heart rates against heart rates recorded during the NIAT indicated that differences between the two conditions were not significant for D and A groups (mean differences were 6.3% and 4.0% respectively). This indicates that the NIAT activity pattern for the positional groups of D and A was close in intensity to that experienced during a match. There was, however, a significant difference between match and NIAT %HR_{max} for the C group (mean difference was 10.0%), indicating that the NIAT did not elicit a similar physiological response as match play for this group, and involved an overall lower intensity than is usually experienced during the game. Sample size in the current study meant that non-parametric statistics were used to analyse the

results and may leave the conclusions open to criticism. It may be that a larger population will be needed before any conclusions can be firmly made as to the validity of the NIAT.

Ecological validity in the current study would refer to the degree in which the NIAT obviously involves performance of netball match play activities. Since the NIAT was based on time motion analysis data from netball match play (Steele & Chad, 1992) it should follow that the NIAT has a good level of face validity. However, some adaptations were made to the time motion analysis data in order to create an activity pattern that was easily replicated and had more control. The NIAT also excluded the use of the ball, except in the A variation where a shooting skill was added. The time motion analysis data used to create the NIAT described a total of 23 different activities. It was felt that this would make the NIAT too complicated and so this was reduced to 10 activities and the proportion of game time spent in each activity adjusted accordingly. Previous authors have identified that intermittent sports protocols need to simulate some components of match play but that they also need to maintain a certain level of control (Davey et al., 2003). It was inevitable, therefore, that the repetition of this smaller group of activity patterns would lead to a higher total number of repetitions than was observed for certain activity patterns in the time motion analysis data (shuffle, sprint, jump). However, there was an overall reduction in the total repetitions of different activities from match play to the NIAT (Differences; A = 528; C=689; D=421). This may contribute towards the significant difference seen in exercise intensity between match play and NIAT for the C group since they have the largest difference in repetitions. Previously,

authors have suggested that changes in activity created a higher energetic demand as a consequence of increased energy expenditure from the need to overcome inertia (Lothian & Farrally, 1995). A comparison of the movement patterns observed in the time motion analysis data and estimated for the NIAT for each positional group is included in Appendix E.

There was also a noticeable difference in the total percent of time spent in various activity patterns for all three positional groups compared to previous TMA data (Steele & Chad, 1992). All three groups spent much more total time shuffling in the NIAT than in match play (A = +12.7%; C = +10.5%; D = +12.0%). The intensity of shuffling is not clear from the literature and so this may have had an effect on the overall activity profile for all positional groups. The A and D positional groups spent noticeably less amount of total time standing than they would do in a match (A = -27.0%; D = -25.9%) and this may have had an influence on their %HR_{max} being artificially closer to that recorded in a game as they would have had much less time at this low intensity recovery and therefore less chance for heart rate to reduce. Centres spent less time jogging than has been observed in a game (-5.9%) and this may have had a different effect on the exercise intensity for this positional group than experienced in a match. However, when reviewing the face validity of the LIST, Nicholas and colleagues (2000) indicated that it was necessary for players to spend less relative time in low-intensity recovery movements such as walking and jogging, and more relative time in high-intensity activities such as cruising and sprinting in their soccer simulation. They attributed this to the self-paced character of a soccer game leading to a natural drop-off in intensity to ensure completion of 90 minutes,

contrasting with the LIST – a structured protocol. It may be necessary, therefore, to adapt the NIAT to ensure it does not take into account a drop off in intense activity as the result of fatigue and have players spend more relative time in high-intensity activities to ensure a structured test that simulates the physiological strain of netball match play.

Research has suggested that certain aspects of time motion analysis data may not have good intra-tester reliability for sports such as rugby union (Duthie et al., 2003). Measures of total time spent in certain individual movements such as walking, jogging, sprinting and standing had only moderate to poor reliability. The time motion analysis data used to develop the NIAT (Steele & Chad, 1991) indicated a good level of reliability, but only compared the movement categories for one subject for the first quarter of the match. It is possible that reliability errors increased with different players or over the duration of the match. Duthie et al. (2003) indicated that it was the lowest (i.e. standing) and highest (striding and sprinting) intensity activities that had the poorest reliability, with even slight differences in these categories causing a noticeable change in overall exercise intensity. Further, it has been recognised that some activities in court sports, such as repetitive shuffling, are more difficult to quantify than running activities (McInnes et al., 1995). Therefore, the quantity of shuffling in the time motion analysis data for netball may be unreliable. If this were the case it is possible that the NIAT does not adequately reflect the actual movement activities of a netball match and offers an explanation for some of the difference in physiological strain observed between the two conditions. In order to gain a better understanding of this relationship it would be necessary to carry out time motion analysis on the subjects whose heart rate data were also being recorded.

It is clear from time motion analysis data in netball (Steele & Chad, 1991) that the majority of movements do not extend beyond 10 s in duration. This suggests a similar pattern to that found in rugby union, where there is particular loading on the Phosphocreatine (PCr) stores for energy production (Docherty et al., 1988), although this only occurs when exercise intensity is high (Powers & Howley, 2001). The latter authors indicate that resynthesis of the PCr stores requires additional oxygen during recovery periods, which would require an increase in heart rate to ensure adequate delivery. This pattern has been observed in other intermittent sports (Drust et al., 2000b). The difference in the current study appears to be that periods of lower intensity exercise in the NIAT are longer but less frequent than in match play. If recovery periods are longer, heart rates will fall lower than those seen in the match situation due to less emphasis on PCr store resynthesis. This likely contributed to the overall lower heart rates seen in NIAT versus match play for all positional groups, but specifically for C group since during match time they have comparably shorter rest periods in between high intensity exercise than they experienced in the NIAT. In fact, this work: rest ratio has been shown to be as important in determining the physical demands of intermittent sports such as rugby union as total time or distance covered at different intensities (McLean, 1992). Otago (1982) indicated that work: rest ratios for a 40 minute netball game were usually 1: 3 or greater, which is different to the NIAT (mean work: rest ratio 1: 7). This may be a reflection of the different match durations, or could simply be an indication that recovery periods in the NIAT are too long compared to actual netball match play. The length of recovery periods accounts for some of the observation that the NIAT is less strenuous

than match play observed through the difference in heart rate data between the two conditions and the lack of noticeable fatigue during the NIAT. However, work: rest ratios for the modern 60 minute game are unavailable and it is likely that the pattern of high intensity exercise to lower intensity recovery in the NIAT is different to that seen in netball match play, particularly for C players.

Previous research has indicated that heart rates during competition are higher than during practice due to psychological influences, indicated by increased catecholamine excretion in competition compared to practice (Baron et al., 1992). In fact, it has been recognised that the psychological stresses of match play are difficult to replicate in a controlled environment and are likely to have an effect on physiological variables affected by psychological factors such as stress and anxiety (Edwards & Clark, 2006; Sari-Sarraf et al., 2006; Antonacci et al., 2007). The authors of the latter two studies recognised that intermittent sport athletes may find it more difficult to replicate the exercise intensity of competition in the absence of strong motivation in experimental settings, and corresponded intensity results from their simulation more closely to those of a training session than match-play. It is possible that in the present study the centre court players felt less motivational arousal during the NIAT than they did during the game and leading to overall lower heart rates.

Szabo et al. (1994) found that during cycling exercise a mild mental challenge was capable of inducing an increase in heart rate compared to when no challenge was

presented. It is likely that the mental challenge associated with netball match play is greater than that elicited in the NIAT for the C group and that this led to the differences in heart rate between the two conditions. A factor that may have contributed to this was the lack of a specific skill to C players in the circuit compared to the D and A groups (defend and shoot respectively). The time motion analysis data (Steele & Chad, 1991) reveals that C players do spend a small proportion of the game defending and guarding (1.3 and 2.5% respectively). It is possible that a specific skill, such as simulated defence of the ball or player could create a mental stimulus that would increase heart rate further during the NIAT for the C group. The lack of specific skill may have also had some bearing on the motivation that the C group felt during the NIAT, resulting in the intensity they completed the test at being lower than they would usually experience during match play. Further research in this area is required.

5.3 NIAT Reliability

5.3.1 Sprint Time

In the present study there was no significant difference in sprint speed over 5 m between trials, correlations between trials were moderate, standard errors and 95% confidence intervals were low, coefficient of variations were acceptable and the 95% absolute levels of agreement indicated only a small amount of random error. These statistics indicate that the sprint element of the NIAT has moderate-good test-retest reliability.

There was also no significant difference in 5-m sprint speed over the duration of the NIAT, indicating that other activity within the NIAT had no fatiguing effect on sprints of this distance. Some authors have recognised the importance of maintenance of sprinting type activity over the duration of other intermittent sports such as soccer, indicating that being able to maintain sprint speed may be a key performance outcome (Edwards et al., 2003; Stroyer et al., 2004). It has also been indicated that soccer players have a reduction in the ability to perform repeated sprints as a consequence of the intermittent profile of the sport (Rebelo et al., 1998). As previously mentioned, it has been suggested that speed endurance in intermittent sports is reliant on the resynthesis of PCr stores (Nicholas et al., 1995), which are involved in energy production for short-term intense exercise such as sprinting (Powers & Howley, 2001). During recovery periods the resynthesis of PCr is normally fairly rapid (Sahlin et al., 1979). When repeated sprints are performed with adequate periods of lower intensity exercise separating them, PCr resynthesis is sufficient to allow maintenance of sprint performance over time (Nicholas et al., 1995). During the NIAT participants are required to perform seven 5 m sprints in each quarter of the game, with each sprint being separated by approximately 2 minutes of generally lower-intensity exercise. It would appear that the NIAT allows for adequate recovery of the PCr energy system to enable sprint speed to be maintained over the duration of the test. It is likely that this is similar to netball match play, where sprinting activity contributes a relatively low proportion to the overall profile (Steele & Chad, 1991), although it may be a reduction in this type of activity that causes the reduced exercise intensity observed towards the end of match play in the current study. The resynthesis of PCr stores also accounts for some contribution to the aerobic loading shown in the heart rate profile of match play, since PCr synthesis relies on the availability of oxygen (Sahlin et al., 1979).

It follows then that heart rates will remain elevated after a bout of short-term high intensity exercise in order to assist in the recovery of PCr stores and will be reflected in the mean %HR_{max} values for match play in the current study. This supports the notion of a decrease in sprint exercise towards the end of the game, since a reduction in the recovery from this type of exercise will result in a decline in exercising heart rate, as seen in the current study.

The mean (\pm SD) 5-m sprint time over the two trials was 1.26 (\pm 0.06) s. This was higher than mean values for National (1.13 \pm 0.07 s) and State (1.15 \pm 0.10 s) level players from Australia when sprinting speed alone was assessed (Ellis & Smith, 2000). The players in the current study were aware of the need to complete multiple sprints and other activities over the course of the test and this may have resulted in a reduction in sprinting speed compared to performing a single sprint. In fact, the sprinting speeds in the current study are more likely to reflect those seen in a game situation when other activity is being performed.

5.3.2 Jump Height

Results for jump height indicated no significant difference between trials of the NIAT. Other reliability tests between the two trials indicated good correlations and low SEM and 95% CI. However, CV indicated that there may have been a certain amount of variance between the two trials and LOA showed a moderate amount of random error. The vertical jump test element of the NIAT appears to have moderate test-retest reliability.

Time appeared to have no significant effect on jump height over the course of the NIAT, with results remaining consistent over the four quarters of the test. It is likely that the explosive action of a vertical jump is also fuelled by the ATP-PCr system, although it has been suggested that a vertical jump test will not tax the ATP-PCr system maximally (Powers & Howley, 2001), and so the length of recovery from this exercise will be shorter than longer periods of higher intensity exercise. With the vertical jump test being performed at the end of each of the seven circuits it is likely that sufficient lower-intensity exercise is performed to allow for the recovery of this energy system so that similar amounts of power are able to be produced over time.

The mean \pm SD vertical jump height over the two trials was 28.97 ± 3.87 cm. This is lower than scores for elite and National players (range 40-62 cm) (Blee et al., 1999; Chad & Steele, 1991; Ellis & Smith, 2000), and State players (range 34-52 cm) when jump height is recorded without any previous strenuous activity. Again, this may be due to participants' prior knowledge of the activity patterns and repetition of jumping ability. However, in the current study participants performed the vertical jump test without the use of an arm swing, which is a different methodology to those used in the comparison studies. It is likely that much of the variation in jump height is due to this methodological difference, and may not allow for good comparison of results.

5.3.3 Circuit Time

No significant difference between NIAT trials was observed for the measure of circuit time. Circuit time between NIAT trials was shown to be moderately correlated, with low

SEM and 95% CI values, acceptable CV and LOA showing only a small amount of random error. This indicates that the test-retest reliability for time to complete the activity circuit in the NIAT is moderate-good.

There was no significant difference between the four quarters of the NIAT in circuit time. This is a good indication that participants completed the circuit at similar exercise intensity over the duration of the test, reflecting a good level of reliability within the circuit activity pattern. The lack of increase in circuit time over the four quarters also indicates that participants were able to maintain the exercise intensity for the duration of the test, and were not adversely affected by any fatigue caused by the pattern of activity. This is likely to be another cause of the discrepancy in %HR_{max} values between matches and NIAT as the activity pattern in the NIAT was not sufficiently strenuous to cause the observed drop-off in exercise intensity seen in match play. It would seem, therefore that the NIAT needs to be adapted to include more high-intensity exercise than it currently involves.

The mean (\pm SD) circuit time over the two trials was 107.69 (\pm 3.77) s. This was, on average, some 22 s below the permitted time to complete the circuit (130 s). However, due to recording logistics time to complete the circuit was recorded from the time the participant stepped on to the vertical jump mat (prior to performing the vertical jump), eliminating this element of the circuit from the total time. Therefore, although the time taken to complete the circuit was less than that allowed, it is probably closer than the

results from this study suggest if the vertical jump performance is taken into account. However, indications that the circuit was performed quicker than the allotted time may reflect a slightly overall higher exercise intensity for the duration of the NIAT than was intended from the time motion analysis data (Steele & Chad, 1991). This is an interesting observation since it would seem that the NIAT does, in fact, elicit a lower physiological response than that observed during a game. This may add weight to the argument that time motion analysis data underestimates the time spent in high-intensity activity or overestimates the time spent in low-intensity activity. Again, for adequate comparison it may be necessary to carry out time motion analysis data on the study participants to gain a clearer understanding of this relationship.

5.3.4 Percent Heart Rate Maximum (%HR_{max})

There was no significant difference in %HR_{max} between NIAT1 and NIAT2 in the current study. The correlation between the two trials was shown to be good, whilst SEM and 95% CI were low, CV was acceptable and LOA indicated only a small amount of random error. This indicates that there is a good level of test-retest reliability for %HR_{max} measures when performing the NIAT.

No significant difference between quarters of the NIAT in %HR_{max} reflected the pattern for circuit time, where exercise intensity remained the same over the duration of the test. This is contrary to the pattern of heart rate activity observed in netball match play in the current study and may give weight to the notion that there is a reduction in activity over the duration of the game, since activity in the NIAT remained the same throughout. It

may be expected during intermittent high-intensity exercise of this nature to observe some cardiovascular drift due to the effects of a rise in core body temperature (Drust et al., 1999). However, the lack of this observation could indicate that the periods of lower intensity exercise within the intermittent profile are sufficient to attenuate any extra stress on the cardiovascular system (Powers & Howley, 2001). Despite consistency over time in the activity intensity in NIAT (as shown by no change in circuit time over time), heart rates did not show signs of cardiovascular drift. The observation of no differences in environmental conditions between match play and NIAT trials adds weight to this argument since cardiovascular drift usually occurs in heated environments. However, more information on the core temperature and hydration status of players during the NIAT would be needed to confirm the presence or absence of cardiovascular drift effects.

The observation of an interaction effect in the NIAT %HR_{max} data revealed that the decrease in %HR_{max} from NIAT1 to NIAT2 was not as large in the 4th Quarter as it was in the 1st Quarter. This may reflect a psychological influence on heart rate data, whereby participants felt a higher level of anxiety during NIAT1, particularly in the first quarter due to the unfamiliar nature of the test and surroundings. Previous studies have shown that exposure to stressful situations will result in an elevation in pre-performance heart rate (Smith et al., 1988), which will inevitably have an effect on performance heart rate if the participants saw the NIAT1 as stressful. Unfortunately, pre-performance heart rates were not recorded in the current study to enable a firm conclusion.

The mean (\pm SD) %HR_{max} over the two trials was $81.8 \pm (4.5)\%$. This is lower than the observed mean %HR_{max} in match play in the current study of $89.6 (\pm 3.4)\%$ and reflects the lower exercise intensity in the NIAT vs. match play, particularly for the C group as previously discussed.

The current study indicates that the NIAT has a moderate level of test-retest reliability for the recorded parameter of vertical jump, moderate-good level of test-retest reliability for 5 m sprint and circuit time, and good test-retest reliability for %HR_{max}. This leads to the acceptance of null hypothesis H03: mean %HR_{max}, sprint times, jump heights and circuit times will not differ between NIAT trials, and also to the conclusion that the NIAT is a repeatable pattern of activity. The lack of a noticeable fatiguing effect on performance of vertical jump and 5 m sprint also leads to acceptance of null hypothesis H04: sprint and jump performance will not change throughout the duration of the NIAT.

5.4 Conclusion

For the current study population it can be concluded that exercise intensity (as measured by %HR_{max}) decreases from the first to the second half of netball match play. Positional differences in exercise intensity have also been observed, with Defenders exhibiting the highest overall cardiovascular strain. This observation has led to the grouping of players into three activity-based positional groups; Defenders (D), Centres (C), and Attackers (A). The NIAT appears to elicit a valid physiological response as measured by %HR_{max}

for D and A, but not for C where exercise intensity in NIAT is significantly lower than in match play. In conclusion, the NIAT is a reliable and valid netball intermittent activity simulation for D and A groups only in the current study population.

5.5 Limitations of the study and recommendations for future research

Some of the results in the current study are limited by sample size, particularly for the validity aspect of the NIAT. Small sample size for these data necessitated the use of non-parametric statistics, which hold less power than their parametric counterparts and may have led to some misleading results. It is suggested that a larger population group is examined in future in order to more adequately assess the reliability and criterion validity of the NIAT.

Much of the time motion analysis and exercise intensity data on netball in the literature is obsolete and may not reflect the demands of the modern game. This may have had an effect of an overall reduction in the intensity of the NIAT compared to match play, possibly allowing for longer recovery times compared to high-intensity bouts. In order to establish if this is the case it is suggested that time motion analysis data is recorded alongside heart rate data for matches, to be compared with the same subjects in performing the NIAT. This would lead to clearer observations of discrepancies in exercise intensity from one condition to the other and will allow for adaptation of the

NIAT activity pattern to more closely replicate that of the modern game. If adaptation occurs then reliability of the NIAT will need to be re-established.

A further limitation of the current study is the lack of other physiological measures to compare between match and NIAT. Blood lactate concentrations or expired air collection may have provided more information about exercise intensity and the roles of specific energy systems within netball. This could have provided valuable comparisons for assessing criterion validity to match play in the NIAT. Any future research into the validity of the NIAT should look at including some of these measures.

Psychological influences may have had a limiting factor on heart rate results in the current study. Participants may have been affected by the effects of anxiety, arousal or motivation, which would have had a resultant effect on the heart rate results for both match play and NIAT. It is difficult to control for any of these influences, however a measure of pre-performance heart rates would indicate the presence of any anxiety in either condition. It may be further necessary to add a mental challenge into the NIAT to replicate the challenges faced during a netball game, possibly adding a decision making skill into the circuit.

Once the validity and reliability of the NIAT has been fully established it will then have the potential to be used to assess how training methods and ergogenic aids might be used to improve netball-related performance parameters.

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APPENDICES

APPENDIX A

The development of a valid and reliable netball performance field test.

PARTICIPANT INFORMATION SHEET

Invitation to Participate in Research Study

My name is Helen Ryan and I am currently preparing a thesis for an M.Sc. in Sport Science at Massey University. This year I am completing a research study to develop a protocol that closely simulates physiological and skill patterns in netball for use in intervention trials. Minimal research has been carried out into the game of netball; in particular the intervention techniques that would help improve match performance. I intend to develop and validate a field test that can be used in the future for netball research.

Participant Recruitment

All participants (over the age of 16) will be recruited from Netball North Harbour Premier teams. There are two parts to this study; Part A and Part B. I aim to recruit approximately 45 participants for the study. During Part A, all participants will be asked to complete a multi-stage shuttle run test ('bleep' test) whilst wearing heart rate monitors. Heart rates will be monitored during NNH Premier competition games. Part B involves performance of the field test on three separate occasions.

Risks/Discomforts of the study include:

- Feeling fatigued from performing maximal exercise in the 'bleep' test (Part A only).
- Feeling fatigued as if you had just played a 60-minute netball game (Part B only).

Project Procedures and Participant Involvement

Part A of the research project involves the establishment of individual heart rate zones for each participant. You will be asked to complete a 'bleep' test protocol whilst wearing a heart rate monitor during a selected training session at your home training venue (30 minutes) or at a pre-arranged time at Massey University Recreation Centre. You will also be asked to complete a Health Screening Questionnaire relating to health status, prior medical issues, and medications taken. This screening questionnaire is used to ascertain information that may conflict with the study, (i.e. if you are taking any medications that may interfere with the outcome of the study), and may ultimately exclude you from participating. The information obtained on all study questionnaires is strictly confidential and will be used for the purposes of the present study only.

Part B of the research project will involve further collection of heart rate data from matches in your NNH Premier competition schedule, and during performance of the research protocol. Should you play in two or more NNH Premier competition games (equivalent to 120 minutes worth of data) you will be asked to provide approximately an hour and a half of your time on three different days. The first day will involve familiarization (approximately 30 minutes) of a 60-minute activity that resembles the activity pattern of a netball game. The activity will involve walking, jogging, cruising, sprinting and utility movements. During this activity heart rate will be recorded.

During the second and third days you will be asked to complete the 60-minute activity while heart rates will be taken. The data will be used to validate the netball specific test.

Participant's Rights

You are under no obligation to accept this invitation. Should you choose to participate, you have the right to:

- Decline to answer any particular question (although in the case of the Health Screening Questionnaire any missing answer will be viewed as a positive statement and may lead to exclusion from the study).
- Withdraw from the study at any time, even after signing a consent form (if you choose to withdraw you cannot withdraw your data from the analysis after the data collection has been completed)
- Ask any questions about the study at any time during participation
- Provide information on the understanding that your name will not be used unless you give permission to the researcher
- Be given access to a summary of the project findings when it is concluded

Confidentiality

All data collected will be used solely for research purposes and has the possibility of being presented in a professional journal. All personal information will be kept confidential by assigning identifiers to each participant. No names will be visible on any papers on which you provide information. All data/information will be dealt with in confidentiality and will be stored in a secure location for five years on the Massey University Albany campus. After this time it will be disposed of by an appropriate staff member from the Sport and Exercise Science department.

Project Contacts

If you have any questions regarding this study, please do not hesitate to contact any of the following people for assistance:

- Helen Ryan: (09)414-0800 ext. 41160; 021 0571187; H.X.Ryan@massey.ac.nz
- Dr. Andrew Foskett (Research Supervisor, Sport and Exercise Science, Massey University): (09) 414-0800 ext.41104; a.foskett@massey.ac.nz
- Dr. Alan Walmsley (Research Supervisor, Sport and Exercise Science, Massey University): (04) 801 5799 ext.6749; a.walmsley@massey.ac.nz

Committee Approval Statement

This project has been reviewed and approved by the Massey University Human Ethics Committee: Northern, Application 06/002. If you have any concerns about the conduct of this research, please contact A/Prof Ann Dupuis, Acting Chair, Massey University Human Ethics Committee: Northern, telephone 09 414 0800 x9054, email humanethicsalb@massey.ac.nz.

Compensation for Injury

If physical injury results from your participation in this study, you should visit a treatment provider to make a claim to ACC as soon as possible. ACC cover and entitlements are not automatic and your claim will be assessed by ACC in accordance with the Injury Prevention, Rehabilitation and Compensation Act 2001. If your claim is accepted, ACC must inform you of your entitlements, and must help you access those entitlements. Entitlements may include, but not be limited to, treatment costs, travel costs for rehabilitation, loss of earnings, and/or lump sum for permanent impairment. Compensation for mental trauma may also be included, but only if this is incurred as a result of physical injury.

If your ACC claim is not accepted you should immediately contact the researcher. The researcher will initiate processes to ensure you receive compensation equivalent to that to which you would have been entitled had ACC accepted your claim.

APPENDIX B

Participant Code: _____

The development of a valid and reliable netball performance field test.

PARTICIPANT CONSENT FORM

This consent form will be held for a minimum period of five (5) years

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I understand that I have the right to withdraw from the study at any time and to decline to answer any particular questions.

I agree to provide information to the researcher on the understanding that my name will not be used without my permission. (The information will be used only for this research and publications arising from this research project).

I agree to participate in this study under the conditions set out in the Information Sheet.

Signature: _____ Date _____

Full Name (printed) _____

Phone Number _____ Age _____ Date of Birth _____

Address _____

Email _____

Witnessed by: _____ Date _____

APPENDIX C

Participant Code: _____

The development of a valid and reliable netball performance field test.

HEALTH SCREEN QUESTIONNAIRE FOR STUDY VOLUNTEERS

This questionnaire is designed to ensure that participants of a research study are currently in good health and have had no significant medical problems in the past. It is also designed to ensure participants' own continuing well being and to avoid the possibility of individual health issues confounding study outcomes.

Please complete this brief questionnaire to confirm fitness to participate:

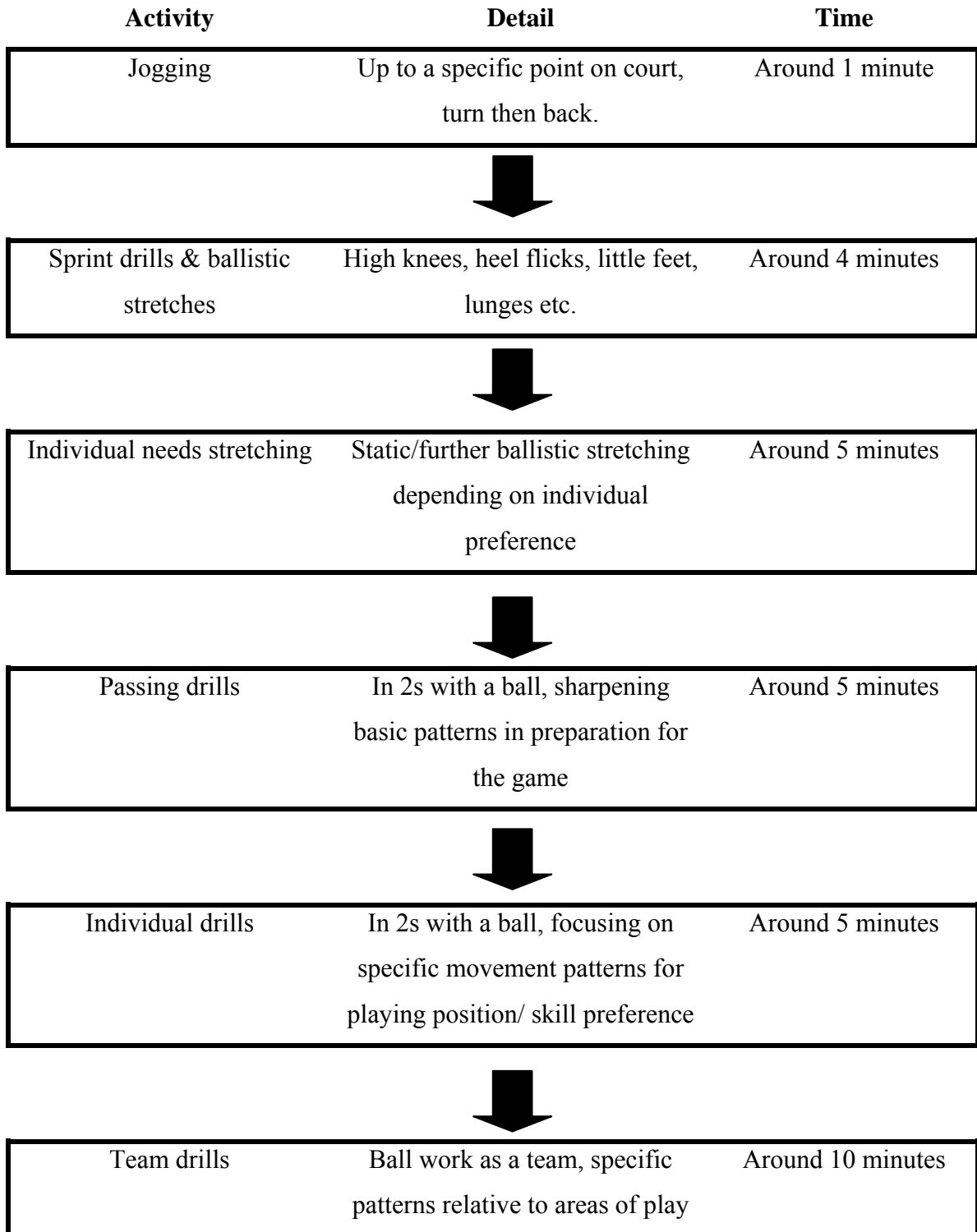
1. **At present**, do you have any health problem for which you are:
 - a. on medication, prescribed or otherwise..... Yes No
 - b. attending your general practitioner..... Yes No
 - c. on a hospital waiting list..... Yes No
2. **In the past two years**, have you had any illness that required you to:
 - a. consult your GP..... Yes No
 - b. attend a hospital outpatient department..... Yes No
 - c. be admitted to the hospital..... Yes No
3. **Have you ever** had any of the following:
 - a. Convulsion/epilepsy..... Yes No
 - b. Asthma..... Yes No
 - c. Eczema..... Yes No
 - d. Diabetes..... Yes No
 - e. A blood disorder..... Yes No
 - f. Head injury..... Yes No
 - g. Digestive problems..... Yes No
 - h. Heart problems..... Yes No
 - i. Problems with bones or joints..... Yes No
 - j. Disturbance of balance/co-ordination..... Yes No
 - k. Numbness in hands or feet..... Yes No
 - l. Disturbance of vision..... Yes No
 - m. Ear/hearing problems..... Yes No
 - n. Thyroid problems..... Yes No
 - o. Kidney or liver problems..... Yes No
 - p. An allergic reaction..... Yes No
4. Has any, otherwise healthy, member of your family under the age of 35 died suddenly during or soon after exercise? Yes No

If YES to any question, please describe briefly if you wish (e.g. to confirm problem was/is short lived, insignificant or well controlled)_____

Thank you for your co-operation!

APPENDIX D

Schematic of standard warm-up



APPENDIX E

Match vs. NIAT Activity Patterns (Time motion analysis, Steele & Chad, 1991 vs. estimated NIAT movement analysis)

For movement patterns involved in NIAT only

Defenders

| Activity | Total Repetitions | | Average Time spent per repetition (s) | | % of Total Time | |
|---------------------------------------|-------------------|------|---------------------------------------|------|-----------------|------|
| | Match | NIAT | Match | NIAT | Match | NIAT |
| Stand | 304 | 192 | 4.2 | 3.1 | 42.9 | 17.0 |
| Walk Forward | 301 | 84 | 2.7 | 8.8 | 27.4 | 21.2 |
| Walk Backward | 132 | 28 | 2.0 | 15.0 | 8.9 | 12.0 |
| Shuffle | 158 | 336 | 1.9 | 2.3 | 10.1 | 22.1 |
| Jog | 107 | 28 | 1.4 | 12.0 | 5.1 | 9.6 |
| Run | 30 | 28 | 1.2 | 4.5 | 1.2 | 3.6 |
| Sprint | 0 | 28 | 0.1 | 1.0 | 0.0 | 0.8 |
| Jump | 43 | 140 | 1.1 | 1.0 | 1.6 | 4.0 |
| Defend | 49 | 168 | 1.8 | 2.0 | 2.9 | 9.6 |
| Shoot | 0 | 0 | 0 | 0 | 0.0 | 0.0 |
| Total | 1123 | 1032 | N/A | N/A | N/A | N/A |
| Total for all match activities | 1453 | N/A | N/A | N/A | N/A | N/A |

Centres

| Activity | Total Repetitions | | Average Time spent per repetition (s) | | % of Total Time | |
|---------------------------------------|-------------------|------|---------------------------------------|------|-----------------|------|
| | Match | NIAT | Match | NIAT | Match | NIAT |
| Stand | 306 | 360 | 2.6 | 2.2 | 24.6 | 22.5 |
| Walk Forward | 375 | 84 | 2.8 | 8.8 | 32.5 | 21.0 |
| Walk Backward | 156 | 28 | 2.1 | 15.0 | 10.1 | 11.9 |
| Shuffle | 247 | 336 | 1.5 | 2.3 | 11.4 | 21.9 |
| Jog | 277 | 28 | 1.8 | 12.0 | 15.4 | 9.5 |
| Run | 92 | 28 | 1.2 | 4.5 | 3.4 | 3.6 |
| Sprint | 3 | 28 | 0.6 | 1.0 | 0.1 | 0.8 |
| Jump | 40 | 308 | 0.8 | 1.0 | 1.0 | 8.7 |
| Defend | 39 | 0 | 1.3 | 0.0 | 1.5 | 0.0 |
| Shoot | 0 | 0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total | 1534 | 1200 | N/A | N/A | N/A | N/A |
| Total for all match activities | 1889 | N/A | N/A | N/A | N/A | N/A |

Attacks

| Activity | Total Repetitions | | Average Time spent per repetition (s) | | % of Total Time | |
|---------------------------------------|-------------------|------|---------------------------------------|------|-----------------|------|
| | Match | NIAT | Match | NIAT | Match | NIAT |
| Stand | 282 | 192 | 4.8 | 3.1 | 44.0 | 17.0 |
| Walk Forward | 272 | 84 | 2.8 | 8.8 | 24.8 | 21.2 |
| Walk Backward | 151 | 28 | 2.1 | 15.0 | 10.3 | 12.0 |
| Shuffle | 180 | 336 | 1.6 | 2.3 | 9.4 | 22.1 |
| Jog | 144 | 28 | 1.3 | 12.0 | 6.1 | 9.6 |
| Run | 58 | 28 | 1.2 | 4.5 | 2.3 | 3.6 |
| Sprint | 2 | 28 | 0.2 | 1.0 | 0.0 | 0.8 |
| Jump | 41 | 140 | 0.9 | 1.0 | 1.2 | 4.0 |
| Defend | 14 | 0 | 1.5 | 0.0 | 0.7 | 0.0 |
| Shoot | 34 | 168 | 1.2 | 2.0 | 1.3 | 9.6 |
| Total | 1177 | 1032 | N/A | N/A | N/A | N/A |
| Total for all match activities | 1560 | N/A | N/A | N/A | N/A | N/A |