THE PHYSIOLOGICAL CHARACTERISTICS OF ELITE WOMEN'S BASKETBALL

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By

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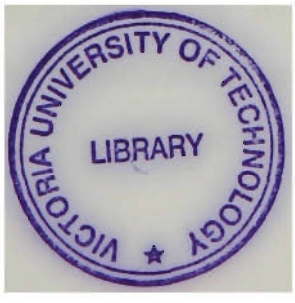

It is concluded that the physiological requirements of elite women's basketball are high, placing considerable demands on the cardiovascular and metabolic capacities of players.

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CHAPTER 1

1.0 INTRODUCTION

Increasing numbers of Australians are playing the sport of basketball. The game's ability to be played both indoors and outdoors, and the international popularity of the game make it an appealing sport for people of all ages. With an impressive 198 countries affiliated with the International Basketball Federation and an incredible 100, 000, 000 (one hundred million) women throughout the world playing basketball, the position of women's basketball has never looked stronger. According to Basketball Australia, females constitute 50% of the registered basketball playing population in Australia with approximately 350, 000 participants. Participation rates have doubled in the last seven years.

One of the factors believed to have contributed to the growth in the number of women playing basketball in Australia, is the increased profile of the Women's National Basketball League (WNBL). According to Leanne Grantham, Chief Executive of the WNBL, record crowds were recorded throughout the 1995/96 seasons with a subsequent rise in the level of media interest. The WNBL was one of Australia's first full home and away sporting competitions for women and is considered to be one of the three most competitive female basketball competitions in the world. This is reflected in the high number of overseas players (imports) who seek to join the competition each year.

Tom Maher, Head Coach of the Australian Senior Women's Basketball Team (Opals), advocates that the standard of the WNBL is in a large way responsible for the success of Australian Junior and Senior Teams at international competitions. The Australian Junior Women's Team (Gems) won a silver medal at the 1997 World Junior Championships and is currently ranked two in the World and the Senior Women's Team, which won its first ever Olympic medal (bronze) at the 1996 Atlanta Olympic Games, is currently ranked three.

Given the increase in the profile of women's basketball both in Australia and overseas, it is interesting to note the limited number of studies which have investigated the physiological requirements of the game. A physiological investigation of elite women's basketball may provide answers to questions such as: What is the nature of the physiological strain incurred by elite players during performance? Which system does the majority of energy contribution during performance come from? What type of specific strength and conditioning is required? Do the physiological stresses placed on elite women basketballers vary according to position?

1.1 RATIONALE

Few studies within the literature have investigated the physiological requirements of elite women's basketball. The rationale behind this study argues that research into the physiological nature of this sport can contribute to a sound scientific basis on which training can be established, for example, the findings can be used to develop strength and conditioning programs specific to the game.

Women's basketball is a highly skilled and tactically based game. Much of the time at training is spent practising offensive and defensive play, accuracy and technique. Limited time remains for specific fitness or strength training. Training involving specific skill related fitness is perceived as desirable for coaches wishing to elicit peak performances from their athletes during competition.

If a better physiological understanding of elite women's basketball can be achieved (absolute and relative heart rate intensities, blood lactate levels, sweat loss) then time-effective training programs can be developed. This information has the potential to be useful for athletes, coaches, sporting associations and physical education professionals.

1.2 THE PURPOSE OF THE STUDY

The purpose of the study was two-fold:

(i) To formulate physiological and anthropometric profiles of elite women basketballers.

(ii) To investigate the relative exercise intensities of elite women basketballers participating in competitive matches.

1.3 LIMITATIONS

In conducting the study, the following limitations are recognised:

1. The environment in which field participation occurred:
   - air temperature
   - humidity
   - air velocity.

   Variations in the above conditions can impact on the rate of sweat evaporation from the skin and elicit variations in heart rate, blood lactate concentration and oxygen uptake during exercise. Given the significance of these factors to the results, it was decided not to conduct field testing in conditions of extreme heat or cold (>32°C and <12°C).

2. The style of the game and the intensity of performance is perceived as another limitation. As the intensity of the game is likely to be proportional to heart-rate, VO_2, blood lactate concentration and sweat loss, subjects were tested as they participated in matches against other WNBL teams or the top four placed teams on the Victorian State Basketball competition ladder. While attempts were made to select an

elite level of competition, not all games were equal in competitive intensity.

3. The nutritional status of the athletes prior to testing creates a further limitation to this project. Given the direct relationship between the ingestion of carbohydrates, muscle glycogen stores and the ability to compete in endurance-based events, all subjects participating in the study were instructed to consume a balanced diet and to avoid excessive carbohydrate ingestion twenty-four hours prior to testing. Measurement of compliance to this advice was not however within the selected parameters of the project.

4. A further limitation was imposed by the nature and quantity of tests performed by the subjects. As previously stated, not all factors considered to influence performance were measured in the testing.

5. The level of motivation and other psychological influences which may be important in performance were not assessed.

1.4 DELIMITATIONS

1. The study was delimited to women basketballers participating in the Australian National Basketball League competition.

2. The number of subjects was restricted to sixteen (eight forwards/centres and eight guards).

3. The strength and conditioning program emphasised low to moderate activity, twenty four to forty-eight hours prior to testing in both the laboratory and field-based sessions.

1.5 DEFINITION OF TERMS

The following definition of terms were adopted for use during the study:

1.5.1 Anthropometric Measures

These terms refer to body size, composition and structure measures:

Height (cm). The linear size measure of the body.

Mass (kg). The total body composition of a person.

Skinfold Measurement. An indication of subcutaneous fat development at a specific site on the body.

Body Mass Index (BMI). Weight/height^2. When weight is expressed as kilograms and height in metres, a BMI over 30 has been associated with obesity in adult women (Thomas, McKay & Cutlip, 1976).

1.5.2 Cardiorespiratory Function Measures

This term refers to the measures adopted to reflect cardio respiratory function of the subjects in the study such as heart rate and oxygen consumption.

Maximal Oxygen Uptake (VO_2 max). The maximal rate of oxygen utilised by a subject during a running treadmill test to volitional exhaustion. It is expressed in absolute terms ($l.min^{-1}$) and in relative terms, as a function of body weight ($ml.kg^{-1}.min^{-1}$).

Submaximal Oxygen Uptake (Submax VO_2). The rate of oxygen uptake at speeds less than the maximal speed recorded during a running

treadmill test to volitional exhaustion. It is expressed in absolute ($l.min^{-1}$) or relative terms ($ml.kg^{-1}.min^{-1}$).

Percent VO_2 max. The use of competition heart rate values to predict the oxygen uptake in field situations which is estimated from the relationship of oxygen uptake and heart rate during a subject's maximal effort on the treadmill $\{Y = a + b(x)\}$.

Percent HR max (% HR max). The mean rate of heart beats in a selected interval within a game situation, expressed relative to the absolute maximal heart rate obtained in the maximal effort treadmill run.

1.5.3 Game-Based Measures

Total Playing Time. This was calculated by adding together the actual playing time and the time taken up by all breaks in play. In simple terms, it is the total time between the start and end of the game.

Live Time. Total playing time minus the time taken up by free throws, time-outs, substitutions and breaks in play. It includes the time taken up by an out of court ball, providing that the corresponding break in play is less than 15 seconds.

1.5.4 Anaerobic Function Measures

Whilst there are a variety of definitions in the literature, the following terms are used to define those characteristics associated with the anaerobic functions of subjects in the context of this research.

Anaerobic Threshold. Anaerobic Threshold (AT) represents the point where a continuing high level of aerobic energy is supplemented by anaerobic energy provision. It could also be interpreted that it is a point

where the increasing addition of anaerobic energy to compliment the aerobic supply eventually results in a situation where lactate is no longer in a steady state.

Lactate Threshold. The highest VO_2 that can be attained during incremental exercise before an observable elevation in blood lactate.

Weltman (1995) provided the following commonly used definitions as a means of defining lactate threshold:

- **change in 1mM** - The VO_2 observed during incremental exercise associated with a blood lactate concentration that is 1 mM above the baseline blood lactate concentration.
- **2.5 mM blood lactate concentration** - The VO_2 observed during incremental exercise associated with a blood lactate concentration of 2.5 mM.

Onset of blood lactate accumulation (OBLA) - The VO_2 observed during incremental exercise associated with a blood lactate concentration of 4.0 mM (Weltman, 1995).

Individual anaerobic threshold (IAT) - The highest VO_2 that can be maintained over time without a continual increase in blood lactate accumulation. IAT is also termed the maximal steady state (MSS) by some research groups.

CHAPTER 2

REVIEW OF LITERATURE

2.0 Introduction

This review is a critique of the physiological characteristics of elite women's basketball. In particular, it focuses on physiological responses in the laboratory and during competitive games. Where there is insufficient information on elite women basketball players during competition, reviews of other intermittent team sports have been included. However, due to differences in sizes of playing areas, duration of games and restrictions to positional movements, this data must be interpreted with caution.

2.1 Anaerobic Threshold

In prolonged exercise with increasing work increments, there is predictable and appreciable dependence on anaerobic metabolism. The point at which this predominance emerges has been the subject of spirited debate for several decades. Specifically the controversy surrounds the concept of an 'anaerobic threshold.' Researchers such as Brooks (1985), Davis (1985) and Skinner and McLellan (1980) have debated issues such as the mechanisms, interpretation, accurate detection and acceptable terminology of the anaerobic threshold. Hughson et al. (1981) even raised doubt about its existence.

In recent years several researchers have reported the presence of two distinct thresholds based on information from ventilatory and blood lactate measurements. Wasserman et al. (1973) defined the anaerobic threshold as the 'level of work or oxygen consumption just below that at which metabolic acidosis and the associated gas exchange occur.' In compiling their definition Wasserman et al. (1973) assumed

that physical activity above a specific intensity resulted in lactic acid being produced in substantially greater concentrations.

2.1.1 Methods of Detection

Green et al. (1983) and Stegmann et al. (1981) reported that a disproportionate increase in blood lactate concentration occurred in subjects during progressive intensity exercise. Caiozzo et al. (1982) and Wasserman et al. (1967) reported marked increases in ventilatory measures during similar bouts of physical activity.

Two distinct methods of detecting disproportionate increases in blood lactate concentration or respiratory measures can be used to ascertain the individual intensity level at which exercise can be maintained for extended periods of time. Brooks (1985) reported that during a series of blood lactate measurements in an incremental prolonged exercise test, the intensity at which deflection or disproportionate increases occurred could be defined as the lactate threshold. The deflection point in ventilatory measurements that occur under similar exercise stresses could be identified as the ventilatory threshold.

2.1.2 Lactate Threshold

Mader et al. (1976) introduced the concept of the 4.0 mM anaerobic threshold which he deemed was the average blood lactate concentration at the subject's lactate threshold. It was originally labelled the aerobic-anaerobic threshold and the concept was further supported by Heck et al. (1985). Kindermann et al. (1979) used the intensity of exercise at a blood lactate of 4.0 mM to characterise anaerobic threshold. The term 'onset of blood lactate accumulation' (OBLA) was later introduced by Sjodin and Jacobs (1981) and represented the exercise intensity at which blood lactate also equalled 4.0 mM. Although these studies reported prolonged physical activity at such intensities, the idea of a fixed blood lactate concentration to describe

lactate threshold in all subjects regardless of gender, climate, training status and morphological differences is questionable.

Stegmann and Kindermann (1981) and Stegmann et al. (1982) introduced the concept of the individual anaerobic threshold (IAT) which takes into consideration individual variations in blood lactate concentrations. The method of calculating IAT involved the measuring of blood lactate concentration during periods of both recovery and physical activity and observing the rise in each individual's blood lactate response. Keith et al. (1992) reported a training-related improvement from exercising at an intensity specified by IAT, whilst Jacobs and Mclellan (1982) and Stegmann and Kindermann (1982) found that exercise at such an intensity could be sustained for long periods of time. Although based on a number of assumptions, which have been questioned, the concept of variable blood lactate concentration at lactate threshold is gaining greater acceptance.

Several investigators (Chwalbinska et al., 1989; Green et al., 1983; Stegmann & Kindermann, 1982) have examined the blood lactate concentration at individually determined anaerobic threshold and reported average values of 2.3, 3.5 and 2.9 and 2.1 mM respectively. Many researchers are now using methods that involve identifying breakpoints in blood lactate concentration for individual subjects. Hughson et al. (1987) used a continuous exponential plus constant model in analysing the blood lactate concentration-VO_2 relationship (cVO_2), and described the curve by the equation: blood lactate = $a + b[\exp(c\ VO_2)]$. Beaver et al. (1985) used a log-log method to emphasise the discontinuous, threshold-like, blood lactate response. Despite disagreement on the criteria denoting the continuous or threshold-like rise in blood lactate concentration, the analysis of individual blood lactate measures is currently common practice.

2.1.3 Ventilatory Threshold

Several parameters have been utilised in measuring ventilatory threshold. Table 2.1 describes a range of authors and the techniques used.

Table 2.1: Summary of Authors and Methods Used to Investigate Ventilatory Threshold

Author	Year	Method
Bunc et al.	1987	Trends in Oxygen Consumption (VO_2)
Costill et al.	1973	Trends in Oxygen Consumption (VO_2)
Davis et al.	1976	Trends in Oxygen Consumption (VO_2)
Davis et al.	1976	Ventilation (V_E)
Ivy et al.	1980	Ventilation (V_E)
Rusco et al.	1980	Ventilation (V_E)
Wasserman and Whipp	1975	Ventilation (V_E)
Davis et al.	1976	Respiratory Exchange Ratio (RER)
Wasserman and Whipp	1975	Respiratory Exchange Ratio (RER)
Wasserman et al.	1973	Respiratory Exchange Ratio (RER)
Beaver et al.	1986	Excretion of CO_2 (VCO_2)
Davis et al.	1979	Excretion of CO_2 (VCO_2)
Rusko et al.	1980	Excretion of CO_2 (VCO_2)
Davis et al.	1979	Ventilatory equivalent for O_2 and CO_2 consumption (V_E/VO_2) (V_E/VCO_2)
Reinhard et al.	1979	Ventilatory equivalent for O_2 and CO_2 consumption (V_E/VO_2) (V_E/VCO_2)
Wasserman et al.	1981	Ventilatory equivalent for O_2 and CO_2 consumption (V_E/VO_2) (V_E/VCO_2)

Most of these methods involve observation of one or two specific parameters over time and/or velocity to identify a threshold. Beaver et al. (1986) used a computerised regression analysis of the VCO_2 versus VO_2 slope (V-slope technique)

collected during progressive intensity exercise, and reported that the computed V-slope technique could more reliably determine the ventilatory threshold than visual inspection of previously described methods using other ventilatory parameters. Orr et al. (1982) used a computerised three-segment regression analysis to determine the intersection of the segments in the V_E vs VO_2 plot. The computerised technique correlated highly (r=0.95) with visual inspection methods.

2.1.4 Excess CO_2

The V-slope technique introduced by Beaver et al. (1986) involved detecting a breakpoint from excess CO_2 ($ExCO_2$) produced by the buffering of non-metabolic acids generated during anaerobic metabolism. The researchers simultaneously measured blood bicarbonate and blood lactate concentrations during progressive intensity physical activity. Beaver et al. (1986) found that in excess of 92% of proton buffering was fulfilled by the bicarbonate buffering system.

2.1.5 Relationship between Lactate and Ventilatory Threshold

Wasserman et al. (1973, 1981) supported the idea of a direct relationship between increases in ventilation and the production of lactic acid. Hollman (1959) and Wasserman and McIlroy (1964) investigated the possibility of detecting the onset of lactic acidosis through changes in gas exchange variables. Numerous studies have since explored similar relationships.

Davis et al. (1976) reported no significant difference in the estimation of anaerobic threshold from gas exchange variables and blood lactate concentration.

Caiozzo et al. (1982) correlated gas exchange and blood lactate methods for determining anaerobic threshold. The authors made comparisons using non-linear increases in V_E or VCO_2, sudden increases in RER (>1.0), an increase in V_E/VO_2

without a corresponding increase in V_E/VCO_2, and increases in blood lactate. The authors found that all except one of the gas exchange methods compared correlated significantly with the blood lactate method as a means of detecting anaerobic threshold. The one exception to the established relationships was the RER.

Reinhard et al. (1979) reported a correlation of r = 0.94 when comparisons were made between the VO_2 at lactate threshold and the VO_2 at ventilatory break-point. Denis et al. (1982) examined the effects of a 40 week endurance training program on ventilatory break-point, lactate threshold and lactate threshold at 4 mM. The authors reported increases in each of the thresholds of 10, 15 and 18% respectively and a lactate and ventilatory threshold correlation of r = 0.79 ($P< 0.001$).

Anderson and Rhodes (1990) compared methods of determining Anaerobic Threshold using the methods of increases in blood lactate concentration, V_E/VO_2 ventilatory threshold and $ExCO_2$ breakaway [$T(ExCO_2)$]. They reported a correlation of r = 0.95 when lactate threshold and $T(ExCO_2)$ were compared, and a correlation of r = 0.91 when lactate threshold and ventilatory threshold were compared. This occurred despite differences in the times at which lactate threshold and the two ventilatory thresholds were reported ($P<0.01$). Anderson and Rhodes (1990) also found that the rise in $ExCO_2$ preceded and mirrored the increase in blood lactate concentration. They suggested that although the release of the by products measured is temporarily offset, a relationship existed between blood lactate accumulation and $ExCO_2$ expiration.

Langill and Rhodes (1992) examined the relationship between $ExCO_2$ and blood lactate during incremental exercise. The authors reported that $ExCO_2$ and blood lactate increased proportionally to each other and demonstrated a non-significant regression slope ($P>0.1$) between 10% relative time and volitional exhaustion. The equation BLa ($mmol^{-1}.l$) = [$ExCO_2(ml.kg^{-1}.min^{-1})$ x 0.314] - 0.586 was derived by the authors to describe the relationship between $ExCO_2$ and blood lactate.

With a plethora of research existing reporting a high incidence of lactate and ventilatory threshold being significantly correlated, it would appear that lactate concentration and ventilatory responses are causally linked. Recent evidence, however, has been presented that refutes the theory of ventilatory and lactate threshold being causally related.

Neary et al. (1985) examined lactate and ventilatory thresholds under both normal and glycogen depleted/previously exercised states. The authors observed no significant change in ventilatory threshold under experimental conditions, and as a result suggested that plasma lactate accumulation was not responsible for a threshold response in ventilation.

Cecca et al. (1986) reported similar findings. The authors again examined lactate and ventilatory thresholds under both normal and previously exercised states. Subjects underwent an incremental cycling test under both normal and previously exercised states, i.e. mean pre-test blood lactate concentration was 9.8 mM. The authors found no significant difference in ventilation at each power output under normal and acidotic conditions.

Poole and Gaesser (1985) assessed adaptations in lactate and ventilatory thresholds using both continuous and interval training methods. The authors observed a significantly greater increase ($P<0.05$) in lactate threshold when compared with ventilatory threshold using continuous training techniques. Poole and Gaesser (1985) reported a poor correlation ($r = -0.13$) between pre and post-training adaptations in ventilatory and lactate threshold and as a consequence suggested that the two thresholds were regulated by different mechanisms.

Gaesser and Poole (1986) reported similar findings with the implementation of a three week training program, i.e. 30 minutes at 70-80% VO_2 max, six days per week. The authors observed that V_E/VO_2 increased well prior to the rise in blood lactate

during incremental exercise when subjects were tested post-training. This led the authors to suggest that ventilatory threshold response was caused by a stimulus other than the onset of blood lactate accumulation.

Hagberg et al. (1982) postulated that patients with McArdle's disease, who do not have the muscle enzyme phosphorylase and are therefore unable to produce lactic acid, display a ventilatory threshold response similar to normal subjects. These observations, however, must be carefully interpreted as McArdle's disease sufferers may in fact exhibit a mechanism for ventilation that compensates for a lack of blood acidosis.

Hughes et al. (1982) measured subjects throughout continuous incremental exercise in normal and glycogen-depleted states. The authors reported that subjects performing under a glycogen-depleted state elicited a significantly greater discrepancy between lactate and ventilatory thresholds. Results indicated an uncoupling of lactate and ventilatory thresholds and suggested that ventilatory threshold was limited in its estimation of anaerobic threshold.

With observations of an independent relationship between lactate and ventilatory threshold, researchers have sought to explain the mechanisms that exist to produce the observed responses distinct to incremental exercise.

Even though a variety of hormonal and neuronal mechanisms have been suggested to explain increased ventilation (Hagberg et al., 1982; Jones & Ersham, 1982; Whipp & Ward, 1980) it is not clear whether one or more of these mechanisms are responsible for the responses observed during incremental exercise.

2.1.6 Activity at Ventilatory Threshold

Despite ventilatory parameters being refuted as a method of accurately determining anaerobic threshold, numerous studies have succeeded in identifying threshold intensities at which exercise can be performed for extended periods.

Rhodes and McKenzie (1984) used nonlinear increases in excess CO_2 as a means of predicting marathon running performance. The authors used the velocity at which the ventilatory threshold was observed to determine marathon running speed and the corresponding competitive performance times. Rhodes and McKenzie (1984) reported a correlation of r = -0.94 between predicted and actual times.

Hearst (1982) examined blood lactate concentration during sets of 10 minute treadmill runs at, above and below ventilatory threshold. The author reported significantly lower concentrations in blood lactate measured at ventilatory threshold when compared to concentrations measured at 1 $km.hr^{-1}$ above ventilatory threshold.

Several studies have examined the relationship between ventilatory threshold, VO_2 max and race performance. Kumangai et al. (1982) compared ventilatory threshold and VO_2 max with running performance over distances of 5 km, 10 km and 10 miles. The authors reported a higher correlation of race performance with ventilatory threshold than with VO_2 max. These results would appear to confirm that the anaerobic threshold is a better determinant of endurance performance than total aerobic capacity.

2.1.7 Activity at Lactate Threshold

2.1.7.1 Performance at a Fixed Blood Lactate Concentration

Kindermann et al. (1979) used a fixed blood lactate concentration of 4.0 mM to predict anaerobic threshold. The authors reported that activity at a workload corresponding to the 4.0 mM level could be maintained for 30 minutes with little change in heart rate and blood lactate concentration. Despite minimal changes in heart rate and blood lactate concentration, both values continued to increase over the full 30 minutes rather than plateau.

Mongoni et al. (1990) examined exercise at a workload corresponding to 4.0 mM. The authors reported that fourteen of the thirty-four subjects were able to complete 60 minutes of exercise, with eight of thirty-four continuing beyond 60 minutes. The mean time of subjects who reached exhaustion prior to 60 minutes was 38.2 minutes. Interestingly, subjects who continued past 60 minutes averaged 4.3 mM, a value closely resembling the 4.0 mM threshold.

Oyono-Enguelle et al. (1990) examined steady-state exercise at a lactate threshold corresponding to 4.0 mM. The authors reported a mean time to exhaustion of 23.5 minutes. Subjects reached on average 81% of VO_2 max. Sjodin and Jacobs (1981) examined the relationship between 'onset of blood lactate accumulation' (OBLA) and marathon running performance. The authors reported a high correlation ($r = 0.96$) between the speed at which OBLA was observed and marathon running speed.

2.1.7.2 Variable Blood Lactate Concentration

The concept of Individual Anaerobic Threshold (IAT) was introduced by Stegmann et al. (1981). Stegmann and Kindermann (1982) compared steady-state exercise of 50 minute duration at IAT to the lactate threshold corresponding to a blood lactate

concentration of 4.0 mM. The authors found that all subjects were able to complete the 50 minute bout at an intensity corresponding to IAT, whether IAT occurred either above, below or at the 4.0 mM blood lactate level.

Schnabel et al. (1989) examined performance at IAT and found that the time subjects could maintain exercise at a constant load ranged from 3 to 36 minutes. Jacobs and McLellan (1988) examined the validity of IAT using a 30 minute cycling test. Although measures of heart rate and their rating of perceived exertion (RPE) increased throughout the test, the authors observed a plateau in blood lactate concentration between the tenth and thirtieth minutes (3.1 mM). McLellan and Cheung (1992) observed that blood lactate concentration increased to 3.9 mM in the first 10 minutes and levelled off in the subsequent 20 minutes during a 30 minute exercise bout at an intensity corresponding to IAT.

Aunola and Rusko (1992) reported that the anaerobic threshold correlated significantly with the occurrence of the maximal lactate steady-state. The authors suggested that because anaerobic threshold and maximal lactate steady-state occurred at different blood lactate concentrations for individual subjects that the concept of a 4.0 mM threshold is erroneous when determining the anaerobic threshold.

Given that there is substantial variation in the techniques used to determine the anaerobic threshold, and as different techniques may elicit a variety of responses during progressive activity, a great deal of caution should be applied to the interpretation of results. In addition, attention should be paid to the individual's unique response to incremental exercise.

Summary

- The anaerobic threshold is generally determined using either blood lactate (lactate threshold) or ventilatory gas (ventilatory threshold) variables. The relationship between lactate threshold and ventilatory threshold is not conclusive.
- Lactate threshold has been characterised using either a fixed or variable blood lactate concentration. Recent studies have used an individual blood lactate concentration to determine anaerobic threshold (individual anaerobic threshold).
- Ventilatory parameters have been used to assess ventilatory threshold, many of which have elicited a threshold response during exercise of a progressive nature.
- Although research exists which supports the concept of a causal relationship between ventilatory threshold and lactate threshold, several studies have reported no significant change in ventilation despite significant increases in blood lactate concentration. Research also exists which uses evidence from subjects with McArdle's disease to refute the possibility of a causal relationship between ventilatory threshold and lactate threshold. Despite these patients not being able to produce lactate, researchers have observed the occurrence of a ventilatory threshold in these subjects during progressive exercise .
- Research exists which suggests that there is a high correlation between performance at the anaerobic threshold and performance in endurance events.
- Many studies exist which support the concept of an individual anaerobic threshold as the level at which exercise can be performed for a minimum of fifty minutes.
- Related to the identification of a variety of responses during progressive exercise, is the need to exercise caution when assessing and interpreting the anaerobic threshold.

2.2 Anthropometry

The unlimited number of studies within the literature which have measured the physical size and proportionality characteristics of elite women basketballers indicate that players tend to have tall powerful physiques, suitable for a game which involves running, agility and a high level of ball control (Bale, 1991).

2.2.1 Height

The majority of studies in the literature have focused on reporting the height of elite women basketballers according to player positions, i.e. guards, forwards and centres.

Spurgeon et al. (1980) studied the height of national Canadian, Czechoslovakian, Polish, Soviet and American female basketball players. The authors reported that when the variables of all the national players were combined, the centres were found to be the tallest. Next tallest were the forwards, followed by the guards.

Smith and Thomas (1991) measured the height of members of the national Canadian Women's Basketball Team. The authors reported mean heights of 176.5 $\pm$ 1.81, 185.1 $\pm$ 0.7, 181.4 $\pm$ 0.7 and 188.5 $\pm$ 2.1 centimetres (cm) for guards, power forwards, shooting forwards and centres, respectively.

Table 2.2 indicates significant differences in the data presented by Smith and Thomas (1991).

Table 2.2: Height (cm) of Elite Canadian Women Basketballers as Reported by Smith and Thomas (1991)

Combined Group (n=29)	**Guards (n=11)**	**Power Forwards (n=6)**	**Shooting Forwards (n=6)**	**Centres (n=6)**
181.8 (± 1.1)	176.5 (± 1.8)[b,c,d]	185.1 (± 0.7)[a]	181.4 (± 0.7)[a,d]	188.5 (± 2.1)[a,c]

Mean ± SEM
[a]Significantly different from guards; [b]from power forwards; [c]from shooting forwards; [d]from centres.

In a study of eighteen members of the English Under 17 female basketball squad (mean = 15.6 years of age), Bale (1991) found that the centres were the tallest, followed by the forwards and then the guards. The differences were significant, particularly between the centres and guards.

Ackland et al. (1994) measured the height of basketball players from 14 national teams competing in the 1994 Women's World Championships in Australia. The authors reported that the guards, forwards and centres recorded mean heights of 171.9 ± 0.8, 181.3 ± 0.8, and 189.3 ± 1.6 cm respectively.

The mean heights of four guards, two forwards and six centres competing with the Australian Senior Women's Basketball Team at the 1994 World Championships were 173.5 ± 2.2, 188.7 ± 2.0 and 188.4 ± 2.6 cm respectively (unpublished data, Andrea Schreiner, Western Australian Institute of Sport). The average height of the 1993 Senior Australian Women's Basketball Squad was 181.3 centimetres (unpublished data, Basketball Australia).

Summary

- The limited number of studies in the literature which have measured the height of elite women basketballers have generally categorised results according to playing position.

- A variety of authors reported that the centres were the tallest. Next tallest were the forwards, followed by the guards.
- Based on the limited number of studies in the literature which have investigated the anthropometric characteristics of elite women basketballers, it would appear that height is a pre-requisite for those basketball players who spend the majority of their time nearest to the basket during competitive performance.

2.2.2 Body Mass

Similar to the description of the height of the women basketballers, the majority of studies in the literature have focused on reporting the body mass of elite women basketballers according to player positions, i.e. guards, forwards and centres. Spurgeon et al. (1980) measured the body mass of national Canadian, Czechoslovakian, Polish, Soviet and American female basketball players. The authors reported that when the variables of all the national players were combined, the centres were found to be the heaviest. Next heaviest were the forwards followed by the guards.

Smith and Thomas (1991) measured the body mass of members of the national Canadian Women's Basketball Team. The authors reported mean body mass values of 67.3 $\pm$ 1.5, 77.1 $\pm$ 1.2, 78.7 $\pm$ 2.3, and 81.1 $\pm$ 2.9 kilograms (kg) for guards, power forwards, shooting forwards and centres, respectively.

Table 2.3 indicates significant differences in the data presented by Smith and Thomas (1991).

Table 2.3: Body Mass (kg) of Elite Canadian Women Basketballers as Reported by Smith and Thomas (1991)

Combined Group (n=29)	**Guards (n=11)**	**Power Forwards (n=6)**	**Shooting Forwards (n=6)**	**Centres (n=6)**
74.5 (± 1.4)	67.3 (± 1.5)[b,c,d]	77.1 (± 1.2)[a]	78.7 (± 2.3)[a]	81.1 (± 2.9)[a]

Mean ± SEM
[a]Significantly different from guards; [b]from power forwards; [c]from shooting forwards; [d]from centres.

In a study of eighteen members of the English Under 17 female basketball squad (mean = 15.6 years of age), Bale (1991) found that centres were the heaviest, followed by the forwards, and then the guards.

Ackland et al. (1994) measured the body mass of basketball players from 14 national teams competing in the 1994 Women's World Championships in Australia. The authors reported that the guards, forwards and centres recorded mean body mass values of 66.1 ± 0.8, 73.3 ± 0.7 and 82.6 ± 2.0 kg, respectively.

The mean body mass values of four guards, two forwards and six centres competing in the Australian Senior Women's Basketball Team at the 1994 World Championships were 67.3 + 3.7, 76.2 + 1.7 and 79.4 + 3.7 kg, respectively (unpublished data, Andrea Schreiner, Western Australian Institute of Sport).

The average body mass of the 1993 Senior Women's Basketball Squad was 75.1 kilograms (unpublished data, Basketball Australia).

Summary

- Similar to height, many of the studies in the literature that have measured body mass generally categorise results according to playing position.

- A variety of authors reported that the centres were the heaviest. Next heaviest were the forwards, followed by the guards.
- Based on the limited number of studies in the literature which have investigated the anthropometric characteristics of elite women basketballers, it would appear that reasonably high body mass is a pre-requisite for those basketball players who spend the majority of their time nearest the basket during competitive performance.

2.2.3 Body Mass Index (BMI)

Body Mass Index (BMI) is calculated by dividing the subject's mass in kilograms by the square of their height in metres, i.e. BMI = mass/height^2 (kg.m^{-2}). According to Sjostrom (1992), BMI does not discriminate between fat and non-fat mass. It is not uncommon for lean athletes to elicit BMI's above 30. Researchers who have examined the relationship between BMI and percent body fat measures have reported only moderate correlations (Bourchard, 1991; Sedgwick & Haby, 1991). Garn (1986) suggested that the use of BMI is dubious during periods of growth, when height is continually changing. The author also reported that long legs decrease BMI scores.

Despite the disadvantages, BMI has been found to relate to total mortality and specific morbidities. Bray (1992) examined the BMI of a variety of subjects. The author suggested that: mortality was very low for subjects with a BMI between 20 and 25; low for subjects with a BMI between 25 and 30; moderate for subjects with a BMI between 30 and 35; high for subjects with a BMI between 35 and 40 and very high for subjects with a BMI greater than 40.

Ducimetiere et al. (1989) examined the relationship between coronary heart disease (CHD) and BMI. The authors reported that CHD sufferers had greater BMI values

than non-sufferers. Seidell et al. (1992) suggested that a high BMI is associated with both gall bladder disease and elevated triglyceride level.

Scores corresponding to various percentiles for BMI in Australian females are provided in Table 2.4.

Table 2.4: BMI ($kg.m^{-2}$) Corresponding to Various Percentiles in Australian Females (Norton and Olds, 1996)

1	2	5	10	20	30	40	50	60	70	80	90	95	98	99
17.4	17.6	19.3	20.0	20.6	21.2	21.8	22.2	22.8	23.4	24.5	27.1	30.3	32.2	33.8

Very few studies in the literature have reported the Body Mass Index (BMI) values for elite women basketballers. Table 2.5, however, presents BMI scores derived from body mass and body length data reported by a variety of researchers.

Table 2.5: Summary of BMI's ($kg.m^{-2}$) Derived from Body Mass and Height Data Described by Various Researchers

Author	**Year**	**Group**	**BMI ($kg.m^{-2}$)**
Hakkinen	1993	Ten women basketballers playing in official league in Finland.	22.3
Bale	1991	Eighteen members of the English Junior Basketball Squad.	21.8
Hakkinen	1991	Nine women basketballers playing in the official league in Finland.	22.5
Crouse et al.	1992	Fifteen women college basketballers (NCAA Division I).	23.1(fall) 23.0 (winter) 22.9 (spring)
Smith and Thomas	1991	National Canadian Women's Basketball Team.	22.5 (combined group) 21.5 (guards) 22.5 (power forwards) 24.0 (shooting forwards) 22.7 (centres)
Ackland et al.	1996	National Team players competing in the 1994 World Basketball Championships.	22.3 (guards) 22.3 (forwards) 22.9 (centres)

Mean

The BMI of the Australian Senior Women's Basketball Squad from 1993 to 1996 as derived from a summary of the physiological assessment of players (unpublished data Andrea Stapff, Basketball Australia) is provided in the table below.

Table 2.6: Summary of BMI Data of Australian Senior Women's Basketball Squad from 1993 to 1996

Year	Height (cm)	Weight (kg)	BMI ($kg.m^{-2}$)
1993	180.6	74.6	22.7
1994	179.6	74.1	22.9
1995	180.3	73.7	22.8
1996	179.7	74.1	22.9
Mean			

The BMI's of four guards, two forwards and six centres competing in the Australian Senior Women's Basketball Team at the 1994 World Championships were 21.0, 21.3 and 22.5 $kg.m^{-2}$, respectively (unpublished data, Andrea Schreiner, Western Australian Institute of Sport).

Summary

- Body Mass Index (BMI) as a measure of body composition is limited in its ability to differentiate between fat and non-fat mass.
- Only moderate correlations have been reported between BMI and percent body fat scores.
- Despite disadvantages, BMI has been associated with mortality and morbidity. Studies, for example, have reported that subjects with high BMI's have been found to have high total mortality, whereas subjects with low BMI's have been found to have low total mortality.
- Few studies in the literature have measured the BMI of elite women basketballers.
- When the body mass and body length data described in the literature is used to derive BMI information for elite women basketballers, values are found to range between 21.5 to 24 $kg.m^{-2}$.
- When the BMI's of elite Australian women basketballers are compared with the percentiles for BMI in Australian females, basketballers would appear to fall between the 20^{th} and 60^{th} percentile.

2.2.4 Skinfolds

In their most useful context, the sum of skinfolds can be used to prescribe training and dietary intervention programs. Increased fat mass is likely to be detrimental to performance. In sports such as basketball that require speed or explosive power any increase in body mass from an excess of fat may decrease acceleration unless increases in force are applied (Norton et al., 1996).

Due to an inflated margin for error when converting a sum of skinfolds to percentages of body fat, a more accurate approach is to use the sum of several sites from the average of three measurements at each site (Walsh, 1996). These sites are both trunkal and peripheral. They include the bicep, tricep, suprailliac, subscapula, abdomen, quadricep and calf. The summing of these skinfolds allows the coaching staff and the player to gain a more reliable estimate of changes in their body composition than percentage values derived from populations not necessarily relevant to the individual being measured. In addition, the sum of skinfolds provides a tangible way of comparing results from test to test.

Bale (1991) measured the sum of six skinfolds of eighteen members of the English Under 17 Female Basketball Squad (mean = 15.6 years of age). The author reported mean values of 6.0, 12.6, 9.6, 10.3, 23.0 and 12.5 millimetres for measurements taken at the bicep, tricep, subscapula, suprailliac, anterior thigh and medial calf, respectively. The sum of the six skinfolds totalled a mean value of 73.7 millimetres.

Smith and Thomas (1991) measured the sum of skinfolds of members of the Canadian Women's Basketball Team. The authors reported mean values for the sum of six skinfolds of 62.2 $\pm$ 4.2, 76.0 $\pm$ 4.0, 85.0 $\pm$ 7.8 and 79.8 $\pm$ 7.3 millimetres for guards, power forwards, shooting forwards, and centres, respectively. The combined group value for the sum of five skinfolds (excluding anterior thigh) of 73.3 $\pm$ 3.2 was 11.4 millimetres or 17.4% less than the Hungarian Women's Basketball Team

measured by Eiben (1981), and 6.7 millimetres or 12.1% less than the sum of four skinfolds (excluding abdominal and medial calf sites) of seven Canadian college level players measured by Bale (1991).

Riezebos et al. (1983) reported an inverse relationship between performance ranking in club and college players and percentage body fat assessed through hydrostatic weighing.

Ackland et al. (1994) measured the sum of skinfolds of female basketball players from fourteen national teams competing in the 1994 World Championships in Australia. The authors (1994) recorded mean values of 84.9 $\pm$ 3.2, 84.4 $\pm$ 3.1 and 98.7 $\pm$ 6.2 millimetres for the sum of nine sites for guards, forwards, and centres, respectively.

The sum of seven skinfold sites of four guards, two forwards and six centres competing with the Australian Senior Women's Basketball Team at the 1994 World Championships were 73.0 $\pm$ 8.4, 89.1 $\pm$ 26.0, and 85.2 $\pm$ 11.5, respectively (unpublished data, Andrea Schreiner, Western Australian Institute of Sport). The sum of eight skinfold sites of the 1993 Senior Australian Women's Basketball Squad was 100.3 millimetres (unpublished data, Basketball Australia).

Table 2.7 outlines the sum of skinfolds specific to basketballers as presented in the literature.

Table 2.7: Summary of Skinfold Data Specific to Women's Basketball

Author and Year	**Group**	**Skinfolds Used**	**Mean of Sum**
Bale (1991)	English Female Junior Basketball Squad	6	73.7 (combined group)
Smith and Thomas (1991)	Canadian Women's Basketball Team	6	62.2 ± 4.2 (guards) 76.0 ± 4.0 (power forwards) 85.0 ± 7.8 (shooting forwards) 79.8 ± 7.3 (centres)
		5	73.3 ± 3.2 (combined group)
Ackland et al. (1994)	Elite Women Basketballers competing in 1994 World Championships	9	84.9 ± 3.2 (guards) 84.10 ± 3.1 (forwards) 98.7 ± 6.2 (centres)
Schreiner (unpublished data)	Australian Senior Basketballers competing in 1994 World Championships	7	73.0 ± 8.4 (guards) 89.1 ± 26.0 (forwards) 85.2 ± 11.5 (centres)
Eiben (1981)	Hungarian Women's Basketball Team	5	84.7 (combined group)

Mean ± SEM

Crouse et al. (1992) examined the percent body fat of fifteen American female college basketballers during fall, winter and spring. The combined mean percent body fat values of 19.4 ± 1.5, 17.9 ± 1.2, and 21.0 ± 1.8 taken at the different stages throughout the competitive season did not differ significantly. The authors concluded that a season of college basketball did not significantly decrease the percent body fat of the athletes. It is possible however, that the athletes were measured when they were in a state of optimum condition and a maintenance effect occurred during the season as a result of their participation.

Hakkinen (1993) studied changes in the physical fitness profile of ten elite Finnish basketballers throughout a competitive season. The author reported mean percentage body fat values of 26.2 $\pm$ 0.7 and 25.8 $\pm$ 0.8 before and after the season, respectively. This represented a non-significant change in the combined subjects' body fat during the entire competitive season.

Summary

- An estimate of body composition from the sum of skinfolds is a useful tool for prescribing training and dietary intervention programs.
- Authors have measured the sum of six or seven skinfold sites for women basketballers and reported values ranging from 62.2 $\pm$ 4.2 to 85.0 $\pm$ 7.8 millimetres for measurements taken at sites including bicep, tricep, subscapula, suprailliac, anterior thigh, mid-abdomen and medial calf.
- Numerous authors have examined the sum of skinfold sites ranging from four through to nine and categorised results according to playing position. Generally, guards have been found to have less body fat than forwards who in turn have been found to have less body fat than centres.
- Despite the chance of an inflated margin for error when converting sum of skinfolds to percentages of body fat, several studies exist which have examined the percent body fat changes in female college basketballers throughout a college season. Such studies reported non-significant changes.

2.3 Aerobic Energy Contribution

Basketball is a game involving continual changes in tempo and requires players to sustain high levels of continuous efforts (unpublished physiological testing protocols, Basketball Australia). The ability to deliver oxygen to muscles and tissues during prolonged bouts of exercise is the basis of sports conditioning and a key characteristic of basketball (Stone & Kroll, 1991). Aerobic power is necessary

to meet the energy demands within a game and assist in recovery from high intensity bouts of exercise. It also enables the athlete to participate for longer during competitive performance and practice at high intensities (Stone & Steingard, 1993).

2.3.1 Maximal Oxygen Consumption

Many studies have investigated the maximal oxygen consumption of female college teams (Samek & Cermak, 1970; Sinning, 1973; Sinning & Adrian, 1968).

Riezebos et al. (1993) measured the maximal aerobic power of female Canadian college and club level players during treadmill running. The authors reported mean absolute and relative VO_2 max values of 3.21 $l.min^{-1}$ and 50 $ml.kg^{-1}.min^{-1}$, respectively.

Smith and Thomas (1991) studied the VO_2 max of members of the national Canadian Women's Basketball Team during treadmill running. The authors reported mean values of 54.3 $\pm$ 1.5, 50.7 $\pm$ 1.0, 47 $\pm$ 1.8 and 50.9 $\pm$ 1.9 $ml.kg^{-1}.min^{-1}$ for guards, power forwards, shooting forwards and centres, respectively. The combined group mean of 51.3 $\pm$ 0.9 was higher than those reported by McArdle et al. (1971), Riezebos et al. (1983) and Vaccaro et al. (1979). These authors studied the maximal aerobic power of college teams and reported mean VO_2 max values ranging from 36 $ml.kg^{-1}.min^{-1}$ to 50 $ml.kg^{-1}.min^{-1}$.

Table 2.8: Maximal Aerobic Power Measurements of Elite Canadian Women Basketballers as Reported by Smith and Thomas (1991)

Combined Group (n=29)	Guards (n=11)	Power Forwards (n=6)	Shooting Forwards (n=6)	Centres (n=6)
51.3 $\pm$ 0.9	54.3 $\pm$ 1.5[c]	50.7 $\pm$ 1.0	47.0 $\pm$ 1.7[a]	50.9 $\pm$ 1.9

Mean $\pm$ SEM

[a]Significantly different from guards; [b]from power forwards; [c]from shooting forwards; [d]from centres.

The mean VO_2 max of the Senior Australian Women's Basketball Team between 1993 and 1996 was 50.15 $\pm$ 0.47 $ml.kg^{-1}.min^{-1}$ (unpublished data, Andrea Schreiner, Western Australian Institute of Sport) with a minimum value of 42.10 $\pm$ 0.47 $ml.kg^{-1}.min^{-1}$ and a maximum value of 59.20 $\pm$ 0.68 $ml.kg^{-1}.min^{-1}$.

Crouse et al. (1992) analysed the VO_2 max of fifteen American college women basketballers during fall, winter and spring. VO_2 max did not change significantly from fall to winter to spring.

Table 2.9 depicts the VO_2 max values of the college basketballers measured by Crouse et al. from fall to winter to spring.

Table 2.9:Aerobic Power Measurements of American Female College Basketball Athletes During Fall, Winter and Spring (Crouse et al., 1992)

Fall	**Winter**	**Spring**
43.9 $\pm$ 1.5 $ml.kg^{-1}.min^{-1}$	44.1 $\pm$ 1.5 $ml.kg^{-1}.min^{-1}$	42.9 + 1.5 $ml.kg^{-1}.min^{-1}$

Mean $\pm$ SEM

Hakkinen (1993) studied changes in the physical fitness profile of ten elite Finnish women basketballers during a competitive season. The author found that the entire competitive season led to no systematic change in the maximum oxygen uptake, i.e. 48.0 $\pm$ 2.1 to 47.0 $\pm$ 1.9 $ml.kg^{-1}.min^{-1}$ recorded during a cycle ergometer test. Hakkinen (1993) also found that along with maximum oxygen uptake, the entire competitive season led to no systemic change in maximum heart rate, i.e. 182.7 $\pm$ 5.7 to 182.5 $\pm$ 7.1 $b.min^{-1}$ recorded during a cycle ergometer test.

2.4 Energy Sources During Intermittent Team Sports

Very few studies have examined metabolic sources of energy during intermittent exercise. Gaitanos et al. (1993) performed muscle biopsies to determine the energy sources throughout 10 x 6 second sprints, interspersed with 30 seconds recovery.

These authors observed that the contribution of creatine phosphate (CP) increased whilst the contribution of anaerobic glycolysis decreased after repeated bouts, suggesting that an inhibition of glycolysis with increasing acidosis resulted in an increased contribution of CP and aerobic metabolism to the energy demands. In addition, they reported that CP levels were not fully restored during the 30 seconds rest.

Boobis (1987) suggested that blood lactate concentrations may indicate the contribution of glycolysis during intermittent exercise but may not provide accurate information on all sources of anaerobic energy as intermittent exercise continues. He suggested that whilst decreases in blood lactate concentrations may indicate decreases in the contribution of the anaerobic system, the lower blood lactate concentrations may in fact be due to an increase in CP contribution.

It is possible that inactive periods during intermittent exercise may provide time for the resynthesis of CP and ATP, ADP and AMP and the return of intramuscular pH levels to resting levels (Balsom et al., 1992; Essen et al., 1977; Harris et al., 1976; Holymard et al., 1988). Sahlin et al. (1979) suggested that the energy used to resynthesise CP during periods of inactivity is supplied by aerobic pathways. Bogdanis et al. (1995) reported that approximately six minutes is required for full recovery of CP. Less than fully restored levels of CP would explain the decrease in the power of subjects observed by Gaitanos et al. (1993) during 10 x 6 second sprints, interspersed with 30 seconds recovery. Therefore, longer recovery periods during intermittent exercise may reduce the contribution of glycolysis and prevent high levels of blood lactate and hydrogen ions accumulating (Saltin 1976; Essen & Kayser, 1978). Low pH has been shown to have an inhibitory effect on various functions within the muscle cell (Chasiotis, 1983; Cooke & Pate, 1990; Danforth, 1965; Donaldson et al., 1978; Edman, 1992). Whilst authors have reported that lactic acid accumulation and low pH can contribute to fatigue (Sahlin, 1986), these may not be the only determinants. McKenna et al. (1996) reported that changes in

intracellular and extracellular ion concentrations affect muscle function and contribute to the development of muscular fatigue during intense exercise.

Shortened recovery periods during intermittent exercise have been found to decrease sprint performance and increase heart rate, blood lactate concentration and VO_2 values (Balsom et al., 1992; Keul, 1973; Margaria, 1969). Therefore, shortened recovery periods do not allow restoration of CP, resulting in a greater reliance on glycolysis to provide energy throughout repeated activity bouts (Holymard et al., 1988; Saltin et al., 1976; Essen, 1978).
Bangsbo (1993) suggested that during prolonged intermittent exercise, fatigue may be related to the depletion of muscle glycogen. However, the author highlighted during soccer performance the issue of fatigue is more complex as the players perform prolonged intermittent exercise interspersed with bouts of maximal activities.

The majority of the literature in this field describes single efforts or intermittent exercise with recovery. Because of the intermittent nature of team sports, it is difficult to make any definite conclusions other than that each of the energy systems play a major role.

2.4.1 Lactic Acid Accumulation

Davis (1979) suggested that lactic acid begins to accumulate exponentially at about 55% of VO_2 max for healthy untrained subjects.

The increase in lactic acid has been attributed to the assumption that where oxygen deficiency occurs under heavy activity, the energy requirement is predominantly met by anaerobic glycolysis as the release of hydrogen exceeds oxidation down the respiratory chain. As a result, excess hydrogen combines with pyruvic acid and lactic acid accumulates (Katz & Sahlin, 1988 and 1990).

Some investigators have used radiotracers to label carbon in the carbohydrate molecule (Brooks, 1985; Donovan & Brooks, 1983). These studies have reported that lactic acid is continually being formed at rest and during periods of light activity. However, under these conditions the formation of lactic acid is matched by removal so the actual lactic acid concentration remains constant.

Stainsby and Brooks (1990) reported that accumulation of lactic acid in fact occurs at a higher intensity than aerobic activity. Up to this point lactic acid production is matched by removal and the accumulation of lactic acid increases concomitantly with exercise intensity.

A variety of researchers have suggested that trained subjects elicit a similar pattern. The major difference between trained and untrained subjects appears to be that the threshold at which lactate accumulates occurs at a higher percentage of the trained athletes aerobic capacity. Endurance athletes, for example, have been reported to exercise at intensities that represent about 80 to 90% of VO_2 max (Conley et al., 1981; Wasserman et al., 1981).

2.4.2 Lactic Acid Accumulation During Competitive Basketball Performance

Despite the increasing use of blood lactate measurements to estimate the anaerobic contribution to the energy demands of intermittent sport, very few studies exist within the literature which report blood lactate concentrations recorded during competitive basketball performance.

McInnes (1993) examined the blood lactate levels of elite male Australian basketballers during competitive basketball performances. The author suggested that prolonged periods of play with little or no rest, resulted in elevated blood lactate concentrations, therefore, placing greater dependence on anaerobic glycolysis. A mean blood lactate concentration of 6.8 ± 2.8 mM was reported.

2.4.3 Lactate Concentrations During Competitive Soccer Performance

Agnevik (1970) examined the blood lactate concentrations of Swedish First Division Soccer players at the completion of a competitive match. The author reported a mean value of approximately 10 mM with the highest single measurement reaching over 15 mM in the soccer players that were monitored.

Ekblom (1986) conducted a larger scale investigation of Swedish First Division soccer players. The author observed mean blood lactate concentrations after the first and second half of 9.5 and 7.2 mM, respectively. Corresponding values for Fourth Division players were significantly lower and were reported to have mean concentrations of 4.0 and 3.9 mM, respectively.

Gerisch et al. (1987) examined blood lactate concentrations of German amateur soccer players and found values of approximately 4-6 mM at half-time and at the end of the game. Similar values were observed for elite Danish and English college soccer players (Rhode & Esperen, 1988; Smith et al., 1993).

Table 2.10 presents a summary of the blood lactate concentrations (mM) recorded during or after competitive soccer performance reported by Bangsbo (1993).

Table 2.10: Blood Lactate Concentrations Measured During and After Competitive Soccer Performance as Reported by Bangsbo (1993)

Author	**Level**	**First Half: During (mM)**	**First Half: End (mM)**	**Second Half: During (mM)**	**Second Half: End (mM)**
Agnevik (1970)	Swedish First Division	-	-	-	10.0 mM
Smaros (1980)	Finnish Second Division	-	4.9 ± 1.9	-	4.1 ± 1.3
Ekblom (1986)	Swedish First Division	-	9.5	-	7.2
Rhode and Espersen (1988)	Danish First and Second Division	-	5.1 ± 1.6	-	3.9 ± 1.6
Gerish et al. (1988)	German Elite Amateur League	-	5.6 ± 2.0	-	4.7 ± 2.2
Smith et al. (1993)	Danish First and Second Division	4.9	-	3.7	4.4
Bangsbo (1993)	Danish League	4.1	2.6	2.4	2.7

Mean ± SD

Interestingly, all authors observed blood lactate concentrations that were lower in the second half compared with the first half. This corresponded with a finding that soccer players covered shorter distances in the second half when compared with the first half; 5.4 and 4.7 km, respectively. This was further reflected in a lower mean heart rate in the second half by approximately 10 $b.min^{-1}$.

2.4.4 Lactate Concentrations of Female Soccer Players During Competitive Performance

Like basketball, very few researchers have investigated the blood lactate concentrations of female soccer players during competitive performance. Ekblom and Aginger (sited Bangsbo) observed blood lactate concentrations at half time and at the end of the game of 5.1 $\pm$ 2.1 and 4.6 $\pm$ 2.1 mM, respectively. Although not conclusive, this would tend to suggest that glycolysis is likely to make a significant contribution to the energy demands of competitive female soccer performance.

2.4.5 Lactate Concentrations During Competitive Squash Performance

A number of studies have investigated blood lactate concentrations during competitive squash performance (Beaudin et al., 1978; Garden et al., 1986). The authors reported blood lactate concentrations ranging from 2 to 4 mM for medium level squash players.

Montpetit (1990) postulated that the likely reason for the low blood lactate concentrations recorded during squash was the high number of rallies lasting less than 10 seconds. The author suggested that approximately eighty percent of the rallies in games played by medium level players lasted less than 10 seconds. Margaria et al. (1969) suggested that high intensity work of durations less than 10 seconds has been shown to produce low blood lactate concentrations. However, these authors used an intensity of less than VO_2 max. Given maximal sprint efforts of less than 10 seconds have been found to produce significant lactate production (Jacobs et al.), it would appear that the intensity of the effort could be a major contributor to the low blood lactate accumulation in medium level squash players.

Montepetit (1990) further indicated that high level squash players produce high intensity rallies lasting longer than 10 seconds and are therefore likely to produce blood lactate concentrations greater than 4 mM. Mercier et al. (1987) reported lactate levels as high as 8 mM for highly skilled squash players.

Therefore, energy for squash played at less than the highly skilled level is likely to be generated by the degradation of adenosine triphosphate (ATP) and creatine phosphate (CP) stored in the muscle (Hultman & Sjoholm, 1983).

2.4.6 Problems Associated with Blood Lactate Measurements

Despite the increasing use of blood lactate measurements to estimate the anaerobic contribution to the energy demands of intermittent sports, there are a number of problems with their use.

Blood lactate represents a balance of production, its entry into the bloodstream and its clearance. Given that blood lactate is constantly being produced and cleared depending on the intensity of activity (Brooks, 1986; Anderson & Rhodes, 1989) these values only give a coarse indication of anaerobic contribution to the energy demands moments prior to the blood sample being taken.

Many studies have examined the relationship between muscle lactate and blood lactate concentrations, both during submaximal and maximal exercise. Karlsson et al. (1972) and Green et al. (1983) reported significantly higher lactate concentrations in muscle compared with blood lactate concentrations. Jacobs and Kaiser (1982) observed that individual muscle lactate values ranged between 4.5 and 14.4 mM when compared with a corresponding blood lactate value of 4.0 mM.

Another problem is related to the duration of activity, which may be too short to elicit a significant rise in blood lactate concentration. Boobis (1987) observed a

muscle lactate concentration of approximately 7 mM following a 6 second sprint, while the blood lactate concentration only rose to 1.8 mM and did not exceed 5 mM during the recovery period. The low level of blood lactate is likely to be caused by the limited release of lactate and a large diffusion space for lactate (Rowell et al., 1986; Kreisberg et al., 1970; Brooks, 1985). Whatever the cause, it would appear that blood lactate values in fact underestimate lactate production.

In studies where blood lactate has been measured during competitive soccer performance, large variations in the values recorded have been observed. As a consequence, single blood lactate measurements are not representative of lactate production during, for example, an entire match. They give little or no indication of the average values that may be produced during the game. Likewise, measurements recorded at the completion of competitive performance give no indication as to the degree of lactate production and clearance from the blood during heavy and light work rates.

Despite these limitations, however, the use of blood lactate measurements during competition may still be of value if a number of capillary blood samples are taken during rather than following the game. This way a better indication of blood lactate concentration during competitive performance can be obtained.

Summary

- Despite an increasing use of blood lactate measurements to estimate the anaerobic contribution to the energy demands of intermittent sport, very few studies exist within the literature which report blood lactate concentrations during competitive basketball performance. One particular study suggested that prolonged periods of play with little or no rest, resulted in elevated blood lactate concentrations (mean blood lactate of 6.8 $\pm$ 2.8 mM) and therefore placed greater dependence on anaerobic glycolysis.

- Studies examining blood lactate concentrations during and after competitive soccer performance have reported mean values ranging from 2.4 to 10 mM. One study examining the blood lactate concentrations of female soccer players reported mean values at half time and at the end of the game of 5.1 $\pm$ 2.1 and 4.6 $\pm$ 2.1 mM, respectively.
- Studies examining blood lactate concentrations during competitive squash performance have reported values as low as 2 to 4 mM for medium skilled players, and values as high as 8 mM for highly skilled players. The difference in lactate values has been attributed to the variation in the length of rallies, with low to moderately skilled players experiencing a high percentage of rallies less than 10 seconds and highly skilled players experiencing a high proportion of rallies greater than 10 seconds.
- A number of problems have been reported with the use of blood lactate measurements to estimate the anaerobic contribution to the energy demands of intermittent sports.
- Blood lactate represents a balance of production, its entry into the bloodstream and its clearance. Given that blood lactate is constantly being produced and cleared depending on the intensity of activity, these values only give a coarse indication of anaerobic contribution to the energy demands moments prior to the blood sampling being taken.
- Studies examining the relationship between muscle lactate and blood lactate concentrations have reported significantly higher lactate concentrations in muscle compared with blood. Another problem is related to the duration of activity, which may be too short to provide a significant rise in blood lactate concentration. Consequently, it would appear that blood lactate values in fact underestimate lactate production.

2.5 Sweat Loss and Body Weight Changes

A variety of authors have reported that dehydration negatively impacts on exercise performance, muscular endurance, mental functioning, thermoregulation and gastric emptying (Buskirk & Puhl, 1989; Sawka, 1992; Williams, 1985). High intensity performance has been found to decrease progressively with 2% dehydration (Ekblom, 1986; Walsh, 1994). Sawka (1992) found that total body dehydration increased core body temperature by 0.15-0.40°C for every 1% decrease in body weight during exercise in heat. However, most studies in this area have focused on endurance runners and cyclists (Broad et al., 1996). Little research has investigated fluid losses and fluid intake practices of team sport players. The majority of studies that have examined this topic have been limited mainly to soccer (Ekblom et al., 1981; Kirkendall, 1983; Mustafa & Mahoumad, 1979; Shepherd & Leatt, 1987).

Bangsbo (1993) determined that high energy turnover in soccer is associated with large scale heat production which has to be eliminated in order to avoid overheating and a consequent deterioration in performance. The author (1993) stated that the majority of heat produced is released from the body by evaporation of sweat, which is associated with loss of body fluid. The rise in core temperature during intermittent sports such as soccer and hockey has been reported to be dependent on the intensity and duration of the activity and recovery periods. Elevated core temperature is further augmented by environmental factors such as temperature, relative humidity, players clothing, sweat loss, and fluid intake (Maughan & Leiper, 1994).

Mustafa and Mahmoud (1979) reported that under extreme conditions a decease in body water greater than 3.5 litres was observed for individual soccer players. Furthermore, they observed fluid losses equivalent to 3.1% of body mass during matches played in environmental conditions of 33°C, 40% humidity and 26.3°C, 78% humidity, respectively. However, fluid loss was reduced to 1.2% body mass during a match played in 13.2°C, 7% humidity.

Maughan and Leiper (1994) and Hawley et al. (1992) reported sweat losses of 0.85-5 litres and fluid intakes of just 0-1.14 litres over a 90 minute game of soccer. An early study conducted by Saltin (1964) reported that decreases in body fluid during soccer performance was around 2 litres under normal weather conditions. These results indicated that moderate to severe dehydration may occur in soccer.

Walsh (unpublished thesis, 1996) calculated sweat loss of 1.0 $\pm$ 0.2 $l.hr^{-1}$ for elite female hockey players during matches in cool (11.6 $\pm$ 2.8°C) and humid (64.8 $\pm$ 14%) conditions. The authors (1996) concluded that performance during matches was not affected by the environmental conditions as body mass was unchanged, indicating that fluid intake was sufficient to match calculated sweat loss.

Broad et al. (1996) measured fluid losses during elite basketball, netball and soccer performance during typical summer and winter exercise. Table 2.11 highlights the sweat rates, fluid intakes and dehydration of team sport players in Summer versus Winter competition.

Table 2.11: Sweat Rates, Fluid Intakes, and Dehydration of Female Team Sport Players in Summer Versus Winter Competition (Broad et al., 1996)

Sport	**Sweat Rate ($ml.hr^{-1}$)**	**Fluid Intake ($ml.hr^{-1}$)**	**%DH**
Netball			
Winter	881 $\pm$ 185	660 $\pm$ 252	0.3 $\pm$ 0.6
Summer	982 $\pm$ 255	520 $\pm$ 192	0.9 $\pm$ 0.5
Soccer			
Summer	220 $\pm$ 408	408 $\pm$ 154	1.2 $\pm$ 0.9
Basketball			
Winter	976 $\pm$ 254	601 $\pm$ 167	0.7 $\pm$ 0.5
Summer	917 $\pm$ 253	599 $\pm$ 170	0.7 $\pm$ 0.5

Mean $\pm$ SD

%DH = (Body weight change - urine output) / initial body weight x 100.

The authors (1996) reported that seasonal variations in dehydration was not as great as expected and concluded that athletes in general do not respond predictably or sensitively to environmental conditions. In addition, the provision of individual water bottles, proximity to drink bottles during sessions, encouragement to drink, rules restricting opportunities for drinking, the number of breaks or substitutions and awareness of personal sweat rates were identified as factors influencing fluid replacement. Based on their findings, Broad et al. (1996) recommended that the general fluid intake goal for women basketballers, netballers and soccer players during competition and training should be 600-1000 $ml.hr^{-1}$.

Although it is true that sweat rate is decreased during cooler temperatures, another issue influencing fluid intakes and sweat loss is the situation in which team sports, such as basketball, train and play indoors in all seasons. Brown and Bannister (1985) reported greater than expected sweat rates when activity was held indoors without the benefits of convective cooling. In addition, sportspeople who train outdoors are able to adapt to cooler conditions by wearing more clothes. In such situations, if fluid intake decreases in response to cooler outdoor temperatures, similar total fluid losses to those observed during exercise in heat may occur (Broad et al., 1996).

The value of maintaining full hydration is well illustrated by the studies of Mountain and Coyle (1992) and Walsh et al. (1994). These researchers reported that at least 80% of sweat loss during exercise needs to be replaced in order to optimise cardiovascular, thermoregulatory and performance responses. In addition, these authors found that larger volumes of fluid intake during exercise were associated with greater cardiac output, greater skin blood flow, lower core temperature and a reduced rating of perceived exertion.

Broad et al. (1996) stated that it is still not known whether the intermittent nature of team sports affects sweat losses differently than continuous, prolonged aerobic

exercise. However, Ekblom (1971) reported that intermittent sports raise the core body temperature higher than continuous exercise at a given oxygen consumption. It appears that the extent of this increase is not only affected by the prevailing environmental conditions but also by the standard of the game. First division soccer players were found to have a higher rectal temperature at the completion of the game when compared with teams from three lower divisions (Ekblom, 1971).

Team sports require a high level of mental functioning in the form of decision making during the game. Gopinathan et al. (1988) reported that players rely on mental functioning for tactical thinking, reading play, anticipation and skill delivery. An increase of more than 2°C in core temperature has been found to significantly impair mental and physical function (Gopinathan et al., 1988; Guyton, 1981). Therefore, air temperature, humidity and the hydration of athletes may all affect the core temperature and body mass loss of athletes. Consequently, these responses may adversely affect performance and in extreme cases, compromise the health of the athlete (Walsh, 1996).

Summary

- It has been reported by a variety of authors that dehydration negatively impacts on performance.
- Most studies examining fluid intake and dehydration have focused on cycling and running.
- Increases of more than 2°C in core temperature may affect both physical and mental performance.
- Rises in core body temperature during intermittent sports such as soccer and hockey appear to be dependent on a variety of factors.
- It is currently not clear whether the intermittent nature of team sports affects sweat loss differently to continuous prolonged aerobic exercise.

- Little is known about the fluid losses and fluid intake practices of team sport players.
- It appears that team sport athletes may not respond predictably or sensitively to environmental conditions.
- Maintaining at least 80% of sweat loss during exercise may help to optimise cardiovascular, thermoregulatory and performance responses.

CHAPTER 3

METHODOLOGY

This chapter describes the research design and methodologies under the following categories:

- research design overview
- subjects
- data-collection procedures under both laboratory and field conditions
- statistical treatment of the data.

3.1 Research Design Overview

An 'observational' research design was employed in the study as the researcher neither manipulated nor experimentally controlled the independent variables of the study.

The investigation involved laboratory and field-based testing of sixteen Women's National Basketball League players (eight guards and eight forwards/centres) who volunteered as subjects for the first and major component of this study. However, this number varied within each test due to variations in the number of willing participants and the occasional loss of data due to technical difficulties.

3.1.1 Laboratory-Based Testing

The following points summarise the nature of testing undertaken by participants in the laboratory-based testing phase of the study:

- selected anthropometric measures (body mass, height, armspan, body mass index, sum of skinfolds)
- continuous incremental VO_2 max test
- incremental lactate profile test.

Table 3.1 describes the laboratory-based testing schedule in the context of the training year.

Table 3.1: Laboratory-Based Testing Schedule in the Context of the Training Year

	General Preparation Phase	**Specific Preparation Phase**	**Competitive Phase**	**Transitional Phase**
Commencement	November	January	April	September
Laboratory Tests	VO_2 max Weight Height Skinfolds	Lactate Profile	No Testing	No Testing

Where subjects presented for field-based testing more than two weeks outside laboratory testing, laboratory tests were re-conducted. Hence, the influence of fitness changes throughout the season on results was reduced.

3.1.2 Field-Based Testing

Field-based testing was conducted during competitive State League and Women's National Basketball League (WNBL) matches within the specific and competitive phases of the training year.

The following points summarise the nature of testing undertaken by participants in the field-based testing phase of the study:

- relative and absolute heart rate intensities
- blood lactate concentration levels
- perceived exertion
- weight loss, fluid intake and sweat loss.

3.2 Description of Subjects

This stage of the study involved, on average, sixteen elite female basketballers ranging from 18 to 30 years of age. However, this number varied within each

test due to variations in the number of willing participants and the occasional loss of data due to technical difficulties. In order to ensure their elite status, only players participating in the Women's National Basketball League were selected. Eight guards and eight forwards/centres were randomly chosen by the head coaches of the teams involved in the study. Nevertheless, the nature of the participation was voluntary.

The criteria used for the selection of the guards group was that these subjects spent the majority of their playing time in either the off guard or point guard position. No differentiation between the off guard and point guard position was made due to the fact that the majority of guards selected for the study were found to rotate between these two positions in any given match.

The criteria used for the selection of the forwards/centres was that the subjects spent the majority of their playing time in either the forward or centre position. No differentiation was made between these positions as the forwards and centres selected for the study frequently rotated between these two positions in any given match.

Players who rotated between the off-guard and the forward position were deemed unsuitable and excluded from the study.

3.3 General Description of Tests Conducted in the Laboratory

The majority of tests were conducted in the Exercise Physiology Laboratory at Victoria University (Footscray Campus). This involved a battery of tests which included aerobic and anaerobic characteristics and morphological measurements of skinfolds, armspan, body mass and height.

Prior to testing, all subjects attended a familiarisation session in the Exercise Physiology Laboratory. Within the following two days, subjects returned to the laboratory for anthropometric and physiological profile testing.

3.4 Specific Data Collection Procedures Conducted in the Laboratory

3.4.1 Aerobic Power

Aerobic power (VO_2 max) was assessed on a treadmill using a continuous incremental protocol. Each subject performed a five minute warm up on the treadmill at a speed of 8 $km.hr^{-1}$ and 0% gradient. After the warm-up, the subject stretched and prepared for on-line data collection. Three minutes of resting data was collected prior to the start of the tests.

Testing commenced with the subjects walking/jogging at 8 $km.hr^{-1}$. The speed was increased 1 $km.hr^{-1}$ every minute until 13 $km.hr^{-1}$ was attained. At this point in the test, 3% grade elevations were imposed every minute until volitional exhaustion. The 13 $km.hr^{-1}$ speed ceiling was set following a series of pre-tests in which subjects were asked to nominate the speed at which they were comfortably challenged to begin running on an incline to exhaustion.

VO_2 max is a physiological measure that was conducted using an on-line open-circuit spirometry system. Expired air volume was collected whilst the subject breathed through a Hans Rudolph two-way valve connected to a Pneumatic digital spirometer. The spirometer was checked pre and post-test with a 3 cm syringe. Sampled expired air was analysed for O_2 and CO_2 content by Applied Electrochemistry Analysers. Calibration of the analysers preceded and followed each test (CIG Melbourne, Analytical Grade Gas).

An IBM PC linked via an A to D converter calculated the data directly from the preceding instrumentation. VO_2 max was taken to be the highest value attained during the test. Following the test, the subject 'cooled down' by exercising at a moderate speed of 6 $km.hr^{-1}$ at 0% gradient until a heart rate less than 120 bpm was reached.

Ventilatory Break Point (VBP) was determined by plotting V_E/VO_2 against V_E/VCO_2. The VBP was identified as the point where V_E/VO_2 increased without a corresponding increase in V_E/VCO_2.

3.4.2 Lactate Profile Data

In order to further understand the physiological characteristics of the subjects, a *lactate profile* test was used to determine lactate threshold (LT). The lactate profile test employed a discontinuous protocol with 3 minutes of running interrupted by 1 minute rest intervals. Subjects commenced walking/jogging at 8 $km.hr^{-1}$ at 0% gradient for three minutes. The speed was increased 2 $km.hr^{-1}$ every three minutes until 12 $kpm.hr^{-1}$. At this point in the test, speed was increased 1 $km.hr^{-1}$ until 13 $km.hr^{-1}$ where a 3% grade elevation was imposed every minute until volitional exhaustion. Heart rate, VO_2, RER and VE values were recorded using the open circuit spirometry and metabolic analysis previously described.

A limitation with a protocol that has relatively large incremental steps is that the sensitivity in determining the breakpoint may be reduced and differences between groups difficult to identify. However, given the number of subjects to be tested and the amount of time needed to perform individual tests, increments of $2km.hr^{-1}$ until 12 $kpm.hr^{-1}$ were used.

At the completion of each three minute increment, subjects straddled the treadmill whilst a blood sample was obtained. A final blood sample was obtained three minutes following volitional exhaustion.

The site was cleansed with alcohol immediately before the skin was punctured. The first two drops were discarded. Between 30 µl and 55 µl of whole blood was collected in capillary tubes commercially prepared with heparin and lysing agents to minimise coagulation. The tubes were mixed for three minutes, sealed

and stored on ice. Samples were analysed in duplicate enzymatically using an Analox LM portable lactate analyser.

Lactate threshold was determined by electronically plotting blood lactate concentrations against VO_2 values. Visual observation of a clear deflection point (i.e. the highest VO_2 before an observable elevation in blood lactate concentration) was made by three independent and practiced researchers.

Although controversial, the onset of blood lactate accumulation (OBLA), i.e. the VO_2 observed during incremental exercise associated with a blood lactate concentration of 4.0 mM (Weltman, 1985), was also identified. Exercise associated with a blood lactate concentration of 4.0 mM has been called the anaerobic threshold by some investigators.

3.4.3 Anthropometric Measures

Anthropometric data collection included body mass, height, body mass index, armspan, and skinfolds.

Standing height was measured using a stadiometer. The subject was required to stand barefoot, in an erect position with both heels, buttocks, upper part of the back and back of the head in contact with the vertical wall. The subjects' head was positioned in the Frankfort plane. On request, subjects took a deep breath and stretched upward while the measurer applied gentle traction along side the jaw bone. A set square was brought down, crushing the hair and making firm contact with the vertex. The measurement to the nearest 0.1 cm was taken before the subject exhaled (Basketball Australia, Physiological Testing Protocols, 1997).

Body mass was measured when subjects were seated on a chair on the Sauter Electronic scales ($\pm$ 0.5 grams) model E1200. Subjects were barefoot and wore the tee shirt and shorts in which they performed their tests. They were required

to sit as stationary as possible. Body mass was recorded to the nearest 0.001 kg. During field measurement, body mass was recorded digitally to the nearest 0.1 kg (Basketball Australia, Physiological Testing Protocols, 1997).

Skinfolds were recorded at five sites on the right side of the body using a set of Harpenden callipers. All measurements were marked prior to testing and were recorded to the nearest 0.1 mm two seconds after the full pressure of the callipers were applied (Ross & Marfell-Jones, 1991). The mean of three trials was recorded as the final score (Behnke & Wilmore, 1974).

The *tricep* skinfold was a vertical fold taken at the posterior mid-acromiale-radiale line parallel to the line of the upper arm. The measurement was taken with the arm relaxed, the shoulder joint slightly rotated (externally) and the elbow extended by the side of the body.

The *subscapular* skinfold was an oblique fold taken with the subject standing erect with their arms by their side. The measurement was taken 2 cm along the line running laterally and obliquely downwards from the subscapulare landmark at an angle of 45°.

The *biceps* skinfold was a vertical fold taken at the anterior mid-acromiale-radiale line so that the fold ran vertically and parallel to the axis of the upper arm. The subject was instructed to stand with the arm relaxed, the shoulder joint slightly rotated (externally) and the elbow extended.

The *supraspinale skinfold* was an oblique fold taken at the point where the line from the iliospinale to the anterior axillary border intersects with the line of the superior border of the ilium at the level of the iliocristale (approximately 5-7 cm above the iliospinale).

The *abdominal* skinfold was a vertical fold taken 5 cm from the right hand side of the midpoint of the navel (omphalion), approximately in the midline of the belly of the rectus abdominis.

Body Mass Index (BMI) was determined by dividing the subjects weight (kg) by the square of their height (m), i.e. weight/height^2. The value obtained was expressed in kg.m^{-2}. A BMI of over 30 kg.m^{-2} has been associated with obesity in both adult men and women (Thomas, McKay & Cutlip, 1976).

Armspan was measured with the subject facing a wall and both their toes and nose touching the wall. The arms were raised to shoulder height with palms touching the wall. With arms outstretched, a measurement was taken from the middle finger of one hand to the middle finger of the other hand on a measuring tape mounted on the wall. A straight edge held at right angles to the measuring tape was used to accommodate the different heights in shoulders, rather than shifting the measuring tape fixed to the wall. Armspan was measured to the nearest 0.1 cm (Basketball Australia, Physiological Testing Protocols, 1997).

3.5 General Description of Tests Conducted in the Field

In order to investigate the intensity of game stresses of subjects participating in competitive matches, it was necessary to collect data in the field as well as in the laboratory.

Absolute and relative heart rate intensities, blood lactate levels, perceived exertion and sweat loss data were collected from sixteen Women's National Basketball League (WNBL) players under field conditions. Testing was conducted during the Victorian Basketball Association State League season and the WNBL competitive seasons.

3.6 Specific Description of Tests Conducted in the Field

3.6.1 Heart Rate Data

Competitive game heart rates were monitored throughout competitive matches to estimate the metabolic stresses incurred by the heart which were accepted as reflecting the corresponding exercise intensities. Heart rate data collection in the field involved the monitoring of heart rates with a Polar P.E. 4000 Sportstester. The monitor was initiated by the ECG signals of the heart being picked up from two electrodes in a transmitter belt which was worn by the subject in alignment with the subxiphoid and V5 positions. The ECG signal was sent via telemetry from the transmitter belt to the microcomputer receiver worn as a wrist watch. Records of the actual heart rates were recorded every 15 seconds for the duration of the match and stored in a memory capacity in the wrist device. The memory was then recalled and printed out on a portable computer system.

3.6.2 Video Analysis

Video data was recorded using a Sony Video 8 Handy Cam video camera. The operator used the zoom function to ensure the player being recorded was taped for the entire match. This included, for example, time-outs, substitutions, out-of-bounds plays and foul shots. These data were transferred to a standard VHS 90 minute tape for analysis.

The video information was used to identify periods in the game in which the subject received rest periods beyond fifteen seconds, i.e. outside the memory time set on the heart-rate monitor. These included time-outs, substitutions, foul-shots, balls out-of-court for extended periods and other breaks in play. This information was then cross-referenced with the competitive heart rate data so that the heart rates corresponding to 'breaks in play' were removed. This allowed 'total game time' and 'live time' heart rate data to be determined.

3.6.3 Blood Lactate Data

Blood lactate data was taken from finger tip sampling at five stages during competitive matches:

(i) 15 minutes prior to the commencement of play

(ii) 10 minutes into the first half

(iii) Half-time

(iv) 10 minutes into the second half

(v) Full-time.

As described previously, the site was cleansed with alcohol immediately before the skin was punctured. The first two drops were discarded. Between 30ul and 55ul of whole blood was collected in capillary tubes commercially prepared with heparin and lysing agents. The tubes were mixed for three minutes, sealed and stored on ice. Samples were subsequently analysed enzymatically using an Analox LM portable lactate analyser.

3.6.4 Ratings of Perceived Exertion (RPE)

Relative perceived exertion was determined using the Borg Scale (Table 3.2).

Table 3.2: The Borg Scale

PERCEIVED EXERTION	SCALE
Very Very Light	6
	7
	8
Very Light	9
	10
Fairly Light	11
	12
Somewhat Hard	13
	14
Hard	15
	16
Very Hard	17
	18
Very Very Hard	19
	20

Subjects were asked to rate the intensity of their performance for the five minute period prior to each individual lactate sample, i.e.

(i) 5 minutes prior to the second lactate sample being taken (10 minutes into the first half)

(ii) 5 minutes prior to the third lactate sample being taken (Half-time)

(iii) 5 minutes prior to the fourth lactate sample being taken (10 minutes into the second half)

(iv) 5 minutes prior to the fifth lactate sample being taken (Full-time).

(v) Full-time.

This information was cross-referenced with the competitive heart rate and lactate data to identify possible relationships between markers of metabolic intensity.

3.6.5 Sweat Loss

Gross estimates of *sweat loss data* during competitive performance was calculated by combining body weight changes and fluid intake during competitive basketball matches. Subjects were weighed in their playing outfit without shoes before and after participation in competitive basketball matches. Their body mass was recorded to the nearest .1 kg. Since one litre of water weighs one kilogram under standard conditions and given sweat is primarily water, one kilogram of weight loss equates with one litre of fluid loss. Weight loss was expressed in kilograms. Urinary output was accounted for in total body mass loss. Fluid intake was determined by measuring the amount of liquid in the player's drink bottle at the commencement of the match, measuring the fluid left at the completion of the match and determining the difference in these values. For example, 1 litre (original amount) - 200 ml (fluid remaining) = 800 ml or .8 litre. Sweat loss was calculated by adding weight loss and fluid intake. The measurement was expressed in kilograms.

Given that measurements were made with subjects in their playing outfits, a limitation to the calculation of sweat loss was in not being able to account for the sweat in subjects outfits and shoes at the conclusion of the game.

3.7 Statistical Design and Treatment of Data

All data are presented in mean and standard error of the mean ($M \pm SEM$). Comparisons among specific groups were made using a SPSS (Version 6.0) Analysis of Variance (ANOVA) program. Where measurements were completed over a time series, the ANOVA analysis included repeated measures for time. Post hoc analysis tests (Neumon Keuls) were used where appropriate. For all statistical comparisons, the alpha level of $P<0.05$ was accepted as significant.

CHAPTER 4

RESULTS

The results of this study will be presented in three major sections; laboratory data, field data, and individual game intensity profiles. Under the laboratory data section, the following perspectives will be presented:

- descriptive characteristics
- maximal effort profiles
- body composition - skinfold measurements
- lactate profile tests.

In the field data section, the following competitive basketball game data will be described under these perspectives:

- absolute and relative heart rate intensities
- blood lactate concentrations
- perceived exertion scores
- weight loss, fluid intake and sweat loss.

In the individual game intensity profile section, the following information will be presented for a random selection of subjects participating in the study:

- competitive game heart rate graphs
- lactate profiles
- absolute and relative heart rate intensities.

4.1 Results of Laboratory Testing

4.1.1 Descriptive Data

The descriptive data of the subjects participating in the study are provided in Table 4.1. The age, body mass, height and body mass index (BMI) of subjects are

presented for the overall group and according to two specific 'on-court' positions, i.e. forwards/centres and guards.

Between group comparisons of the forwards/centres and guards indicated that the guards were 14.3 kg or 17.6% lighter ($P<0.05$) and 13.6 cm or 7.4% shorter ($P<0.05$) when compared with the forwards/centres. Non-significant differences ($P>0.05$) were found in group comparisons for age and BMI. Individual results are presented in Appendix [1].

Table 4.1: Descriptive Data of Women's National Basketball League Players

Group	**Age (yr)**	**Mass (kg)**	**Height (cm)**	**BMI ($kg.m^{-2}$)**
Overall Group (N = 14)	23 (± 1)	74.4 (± 3.2)	177.2 (± 2.3)	23.6 (± 0.6)
Guards (N = 7)	23 (± 1)	67.2* (± 1.9)	170.5* (± 2.0)	23.2 (± 0.5)
Forwards/Centres (N = 7)	25 (± 2)	81.5 (± 4.8)	184.0 (± 1.7)	24.0 (± 1.0)

Mean ± SEM

* denotes main effect for group with the asterik mean being smaller than mean of other group

Please Note: The number of subjects varied in this test due to variations in the number of willing participants and the occasional loss of data due to technical difficulties.

4.1.2 Maximal Effort Data

The maximal effort characteristics (VO_2 max) of the subjects participating in the study are presented in Table 4.2.

VO_2 max ranged between 43.85 and 56.61 $ml.kg^{-1}.min^{-1}$ with a mean score of 48.88 (± 1.18) $ml.kg^{-1}.min^{-1}$. Between group comparisons of the relative maximal oxygen consumption ($ml.kg^{-1}.min^{-1}$) of the guards and forwards/centres indicated no difference ($P>0.05$), despite the guards averaging slightly higher scores than the forwards/centres (1.16 $ml.kg^{-1}.min^{-1}$). This small difference could however, represent biological

variability or technical error of measurement. Individual results are presented in Appendix [3].

Heart rate at maximum effort (HR max) ranged between 173 and 206 beats per minute ($b.min^{-1}$) with a mean value of 193 (± 3) $b.min^{-1}$. HR max did not differ between groups ($P>0.05$).

The respiratory exchange ratio obtained during VO_2 max tests (RER max) ranged between 1.05 and 1.30, with a mean value of 1.20 (± 0.02). Between group comparisons of the forwards/centres and guards revealed no difference in RER max ($P>0.05$). Individual RER data are summarised in Appendix [3].

A summary of the data in the Table 4.2 points to the homogeneity of the groups participating in the study. The between group differences in maximal aerobic potential were generally minimal when expressed per kilogram of body mass.

Table 4.2: Maximal Effort (VO_2 max) Characteristics of Women's National League Basketball Players

Group	**VO_2 max ($l.min^{-1}$)**	**VO_2 max ($ml.kg^{-1}.min^{-1}$)**	**RER max**	**Max HR ($b.min^{-1}$)**
Overall Group (N = 14)	3.62 (± 0.17)	48.88 (± 1.18)	1.20 (± 0.02)	193 (± 3)
Guards (N = 7)	3.32 (± 0.14)	49.46 (± 1.68)	1.21 (± 0.02)	193 (± 4)
Forwards/Centres (N = 7)	3.93 (± 0.28)	48.30 (± 1.76)	1.18 (± 0.03)	194 (± 3)

Mean ± SEM
RER = Respiratory Exchange Ratio
Please Note: The number of subjects varied in this test due to variations in the number of willing participants and the occasional loss of data due to technical difficulties.

4.1.3 Body Composition: Skinfold Measurements

Table 4.3 summarises the skinfold measurements of the subjects participating in the study.

The sum of five sites was used as an estimate of skinfold thickness contributing to body composition. The sum of the sites measured ranged between 38.4 and 90.9 mm with a mean score of 62.2 (± 3.2) mm. Between group comparisons revealed non-significant differences in four of the five sites and the total sum of the skinfolds ($P>0.05$). The one exception occurred in the mid-abdomen skinfold site with the guards measuring 5.6 mm or 27.5% lower than the forwards/centres.

Table 4.3: Skinfold Measurements of Women's National Basketball League Players According to Position

Group	**Skinfolds (mm)**					
	Bicep	**Tricep**	**Subscapula**	**Suprailiac**	**Mid-Abdomen**	**Total**
Overall Group (N = 19)	7.9 (± 0.6)	16.8 (± 1.3)	10.7 (± 0.6)	10.3 (± 0.9)	17.4 (± 1.3)	62.2 (± 3.2)
Guards (N = 10)	7.3 (± 0.4)	17.1 (± 1.5)	10.1 (± 0.7)	8.7 (± 6.8)	14.8 * (± 1.5)	58.1 (± 3.5)
Forwards/ Centres (N = 9)	8.6 (± 1.2)	16.4 (± 2.1)	11.3 (± 1.1)	12.1 (± 1.7)	20.4 (± 1.9)	66.9 (± 5.2)

Mean ± SEM

* denotes main effect for group with the asterik mean being smaller than mean of other group

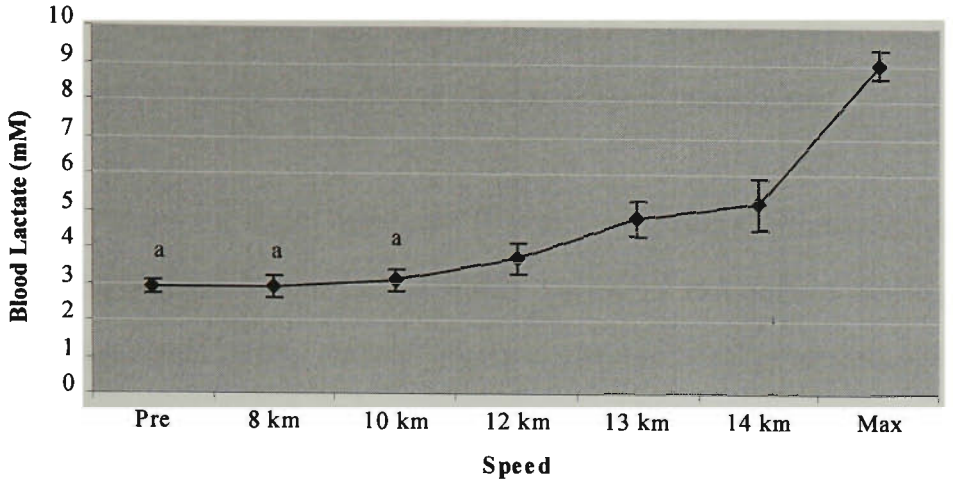
Please Note: The number of subjects varied in this test due to variations in the number of willing participants and the occasional loss of data due to technical difficulties.

4.1.4 Lactate Profile Data

Figure 4.1 presents the mean blood lactate concentrations of the total group during an incremental treadmill test.

Analysis of the total group (Appendix [8]) indicated that the mean blood lactate concentrations recorded prior to testing, at 8 $km.hr^{-1}$ and at 10 $km.hr^{-1}$ were lower ($P<0.05$) than the mean blood lactate concentration recorded at 13 $km.hr^{-1}$. The mean blood lactate concentration recorded three minutes after volitional exhaustion was higher ($P<0.05$) than the mean blood lactate concentrations at all preceding speeds.

Figure 4.1: Mean Lactate Profile of Elite Women Basketballers



a - denotes lower lactate than at 13 km.hr^{-1}

Between group comparisons (Appendix [11]) indicated differences ($P<0.05$) in blood lactate concentrations at speeds of 10, 12 and 13 km.hr^{-1}. At these speeds, the forwards/centres recorded values 1.3 mM or 55.4%, 1.8 mM or 65.2% and 2.5 mM or 73.4% higher, respectively, than the mean blood lactate concentrations recorded by the guards. No differences between the groups ($P>0.05$) were recorded in the samples taken prior to the test, at speeds of 8 km.hr^{-1} and 3 minutes after maximal effort. Because of the limited number of subjects, comparisons at 14 km.hr^{-1} could not be made.

Table 4.4: Lactate Profile Data of Women's National Basketball League Players According to Position

Position	**Blood Lactate Concentrations (mM) at Specific Speeds**						
	Pre-Test	**8 km.hr^{-1}**	**10 km.hr^{-1}**	**12 km.hr^{-1}**	**13 km.hr^{-1}**	**14 km.hr^{-1}**	**Max**
Forwards/ Centres (N = 8)	3.2 (± 0.3)	3.4 (± 0.4)	3.7 * (± 0.5)	4.6 * (± 0.7)	6.1 * (± 0.9)	6.4 (± 1.9) [N=2]	9.7 (± 0.6)
Guards (N = 8)	2.5 (± 0.3)	2.5 (± 0.3)	2.4 (± 0.3)	2.8 (± 0.2)	3.5 (± 0.5)	4.6 (± 0.6) [N=4]	8.2 (± 0.4)

Mean ± SEM

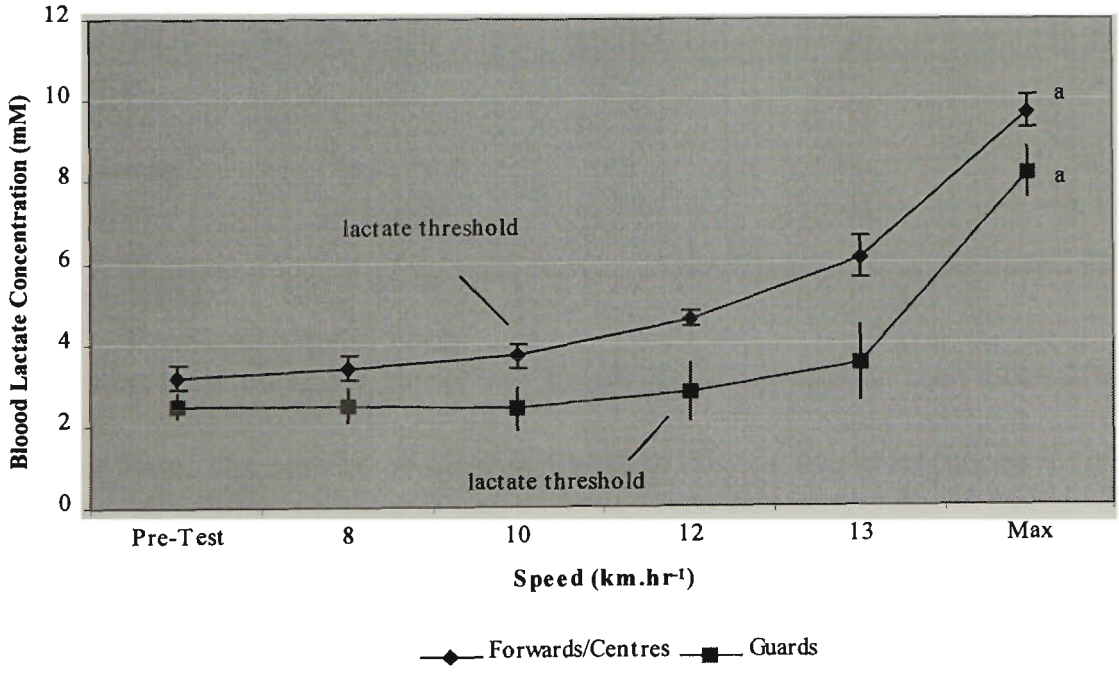
* denotes between group differences in lactate

Analysis of data from the forwards/centres (Appendix [10]) indicated that the mean blood lactate concentrations recorded prior to testing, at 8 $km.hr^{-1}$, 10 $km.hr^{-1}$, 12 $km.hr^{-1}$ and 13 $km.hr^{-1}$ were significantly lower ($P<0.05$) than the mean blood lactate concentration recorded three minutes after volitional exhaustion.

Analysis of the guards data (Appendix [9]) indicated that the mean blood lactate concentration measured three minutes after volitional exhaustion was higher ($P<0.05$) than the mean blood lactate concentrations measured at all preceding speeds.

Between group comparisons indicated a difference ($P<0.05$) in the time in the test in which a lactate threshold was observed. The lactate threshold of the guards was found to occur at a mean speed of 12 $km.hr^{-1}$ whereas the lactate threshold of the forwards/centres was found to occur at a mean speed of 10 $km.hr^{-1}$ [Figure 4.2].

Figure 4.2: Lactate Thresholds of Elite Women Basketballers According to Position



a - denotes value higher than all preceding lactate recordings

4.1.5 Ventilatory Break Point Data

Table 4.5 describes the ventilatory break point of subjects during an incremental treadmill test to volitional exhaustion.

Between group comparisons indicated a difference ($P<0.05$) in the time in the test in which a ventilatory breakpoint was observed. The ventilatory break point for the guards was found to occur 0.83 minutes (50 seconds) further on than that of the forwards/centres. In essence, it represents an additional workload before a break occurred. Despite this distinction, no difference ($P>0.05$) was found in the heart rates at which the ventilatory break point was observed for both groups, or in the heart rates when expressed as a percentage of heart rate maximum.

Table 4.5: Ventilatory Break Point (VBP) Results of Elite Women Basketballers During an Incremental Treadmill Test

Position	**Time (min)**	**VBP Heart Rate ($b.min^{-1}$)**	**Max HR ($b.min^{-1}$)**	**Relative VBP (%HR Max)**
Overall (N = 17)	6.81 (± 0.15)	184 (± 2)	193 (± 2)	95 (± 0)
Guards (N = 8)	7.25 (± 0.21)	184 (± 2)	193 (± 3)	95 (± 1)
Forwards/ Centres (N = 9)	6.42 * (± 0.22)	183 (± 3)	194 (± 3)	94 (± 1)

Mean ± SEM

VBP = Ventilatory Break Point

* denotes main effect for group with asterik indicating smaller than mean of other group

Please Note: The number of subjects varied in this test due to variations in the number of willing participants and the occasional loss of data due to technical difficulties.

4.2 Field Testing Results

4.2.1 Absolute and Relative Heart Rate Intensities

Heart rate data used to indicate field intensity was collected using a portable heart rate monitoring system (Polar Sports Tester™) during competitive basketball performance. Table 4.6 presents the absolute and relative heart rate values recorded during two, twenty minute halves of competitive basketball.

Table 4.6: Absolute and Relative Heart Rate Intensities of Elite Women During Competitive Basketball Performance

Position	Maximum HR# ($b.min^{-1}$)	Mean HR Live Time ($b.min^{-1}$)	Relative HR Live Time (% HR Max)	Mean HR Total Game ($b.min^{-1}$)	Relative HR Total (% HR Max)
Overall Group (N=12)	194 (± 3)	177 (± 0)	91 (± 0)	155 (± 5)	80 (± 2)
Guards (N=6)	193 (± 5)	176 (± 5)	91 (± 1)	159 (± 8)	82 (± 2)
Forwards/ Centres (N=6)	195 (± 3)	179 (± 4)	91 (± 1)	151 (± 5)	778 (± 2)

Mean ± SEM

Heart rate maximum recorded during laboratory testing

Please Note: The values for HR max in Table 4.6 differ to those in 4.5. This is due to associated data being taken from both the incremental test and the lactate profile test. In addition, the number of subjects varied in this test due to variations in the number of willing participants and the occasional loss of data due to technical difficulties.

Mean absolute live time heart rates ranged from 156 to 190 $b.min^{-1}$, and mean relative live time heart rates ranged from 90 to 94% HR max. Mean absolute total game heart rates ranged from 122 to 176 $b.min^{-1}$, and mean relative total time heart rates ranged from 70 to 87% HR max.

Between group comparisons revealed no difference ($P>0.05$) in the live time and total game heart rate results of the guards and forwards/centres. No differences were found when between group comparisons were expressed as a relative percentage of

maximum heart rate values recorded during an incremental treadmill test to volitional exhaustion (P>0.05).

4.2.2 Blood Lactate Concentrations

Table 4.7 delineates the blood lactate concentrations of subjects during elite competitive basketball performance.

Table 4.7: Blood Lactate Concentrations of Elite Women Basketballers During Competitive Basketball Performance

Position	**Blood Lactate Concentrations (mM) at Specific Game Intervals**				
	Pre-game	**10 min First-Half**	**Half-Time**	**10 min Second-Half**	**Full-Time**
Overall Group (N = 15)	2.7 (± 0.2)	7.4 (± 0.2)	5.2 (± 0.5)	5.6 (± 0.9)	4.4 (± 0.6)
Guards (N = 7)	2.7 (± 0.4)	7.3 (± 1.1)	5.7 (± 0.9)	6.2 (± 1.8)	5.2 (± 1)
Forwards/ Centres (N = 8)	2.7 (± 0.3)	7.5 (± 0.8)	4.9 (± 0.5)	5.1 (± 0.7)	3.5 (± 0)

Mean ± SEM

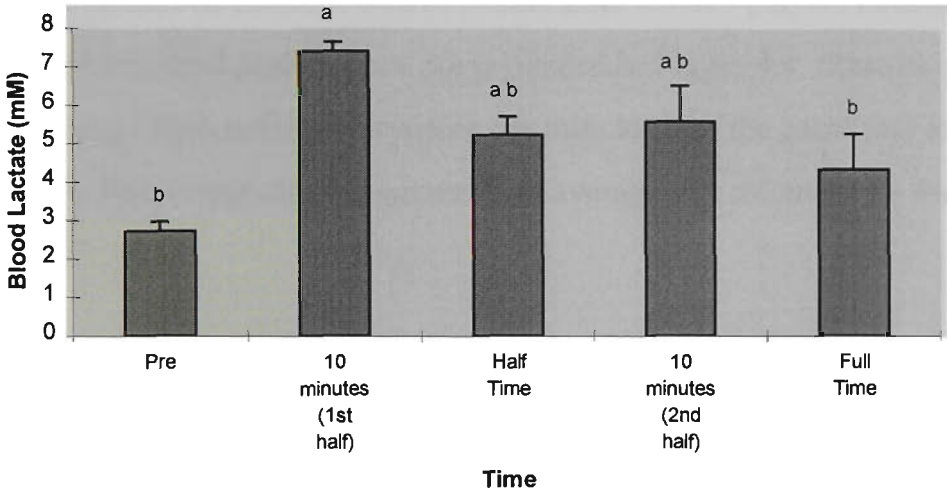
Blood lactate concentrations recorded during competitive performance ranged from 1.2 to 16.3 mM (Appendix [15] & [16]).

Between group comparisons revealed no difference in the blood lactate recordings of the guards and forwards/centres at similar sampling intervals throughout the game (P>0.05).

Figure 4.3 demonstrates the blood lactate concentration results of the overall group data for the main effect of time. The most significant finding was that the mean blood lactate value recorded ten minutes into the first half was higher (P<0.05) than the values recorded at every other stage of the game.

In addition, three out of the four blood lactate values measured during the game were found to be higher ($P<0.05$) than the pre-game value. The blood lactate values recorded at ten minutes into the first half, at half-time and at ten minutes into the second half were higher ($P<0.05$) than the mean of the sample taken prior to the commencement of play. The one exception to this trend was that the mean full-time lactate value was not different from the pre-game value.

Figure 4.3: Blood Lactate Concentrations of Overall Group of Elite Women Basketballers Recorded During Competitive Basketball Performance



a - denotes value greater than that recorded prior to the game
b - denotes value less than that recorded at 10 minute mark of first half

4.2.3 Body Mass Loss

Table 4.8 describes the net body mass loss of sixteen elite women players during competitive basketball performance.

Analysis of the data indicated that the players who participated in the game analysis did not consume enough fluid to maintain their pre-game weight despite consuming a mean of 1.0 litres of fluid throughout the game. On average, players dropped 0.2 kg in body weight which equated to an estimated sweat loss of 1.1 litres per monitored game. Estimated sweat loss throughout a game ranged from 0.7 to 1.9 litres (Appendix 19).

Table 4.8: Total Body Mass Loss of Elite Women Basketballers Measured During Competitive Performance

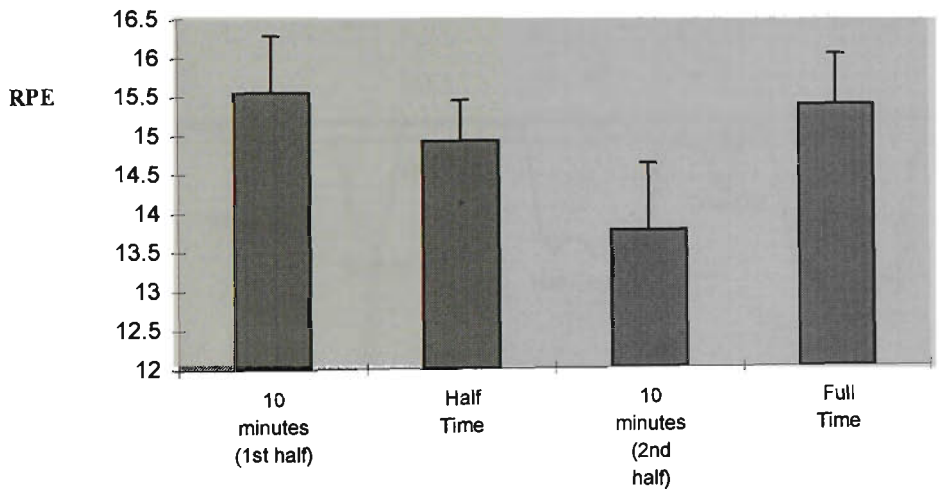
Body Weight Loss (kg)	**Fluid Intake (litres)**	**Net body mass loss / Estimated Sweat Loss (litres)**
0.2 (± 0.1)	1.0 (± 0.1)	1.1 (± 0.1)

Mean ± SEM
N=16

4.2.4 Relative Perceived Exertion Scores

The relative perceived exertion data of twelve elite women players measured during competitive basketball performance are presented in Figure 4.4. Results indicated similar values of high ratings of exertion ten minutes into the game and at the end of competition. The lowest ranking occurred on average, ten minutes into the second half of the game.

Figure 4.4: Relative Perceived Exertion Scores of Elite Women Players at Varying Stages During Competitive Basketball Performance



4.3 Individual Game Intensity Profiles

4.3.1 Heart Rate Responses

The heart rate values of eight randomly selected elite women players (3 guards, 3 forwards and 2 centres) were recorded during Victorian State League and Women's National Basketball League games.

Figures 4.5, 4.6 and 4.7 present the individual heart rate responses of three elite women basketballers during competitive basketball games. The figures indicated that heart rates of each of the players remained high throughout competitive games but dropped instantaneously in response to continuous breaks in play. Extended breaks in play include time-outs, foul shot shooting, substitutions, and half-time intervals.

Figure 4.5: Heart Rate Response of Subject 1 (Guard) During Competitive Basketball Performance

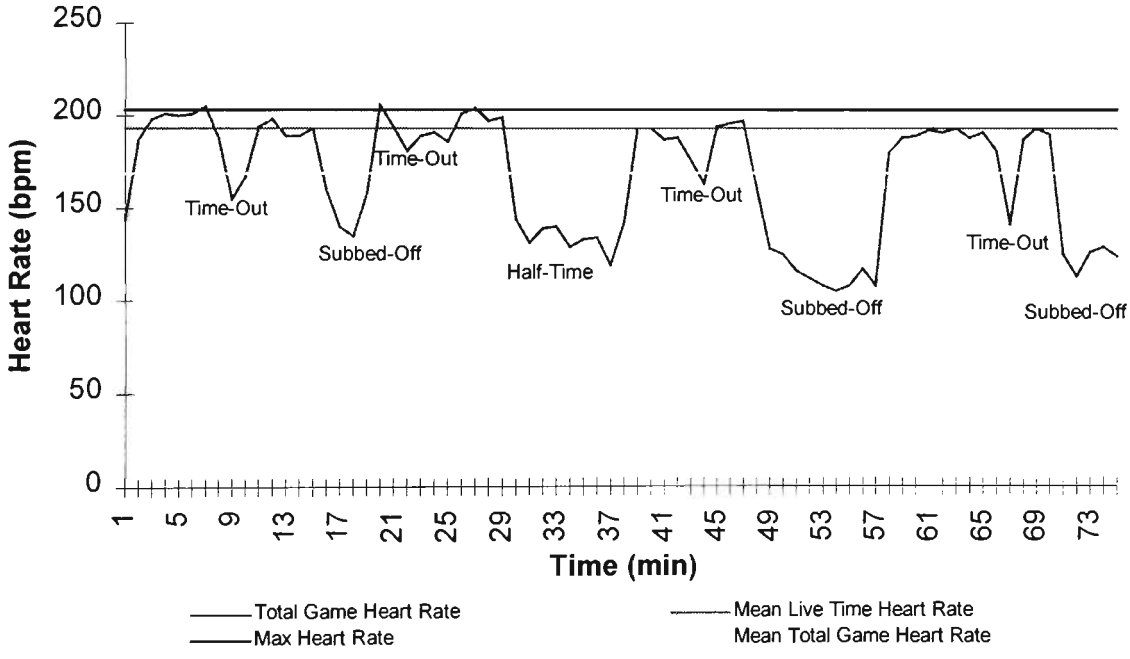


Figure 4.6: Heart Rate Response of Subject 2 (Forward) During Competitive Basketball Performance

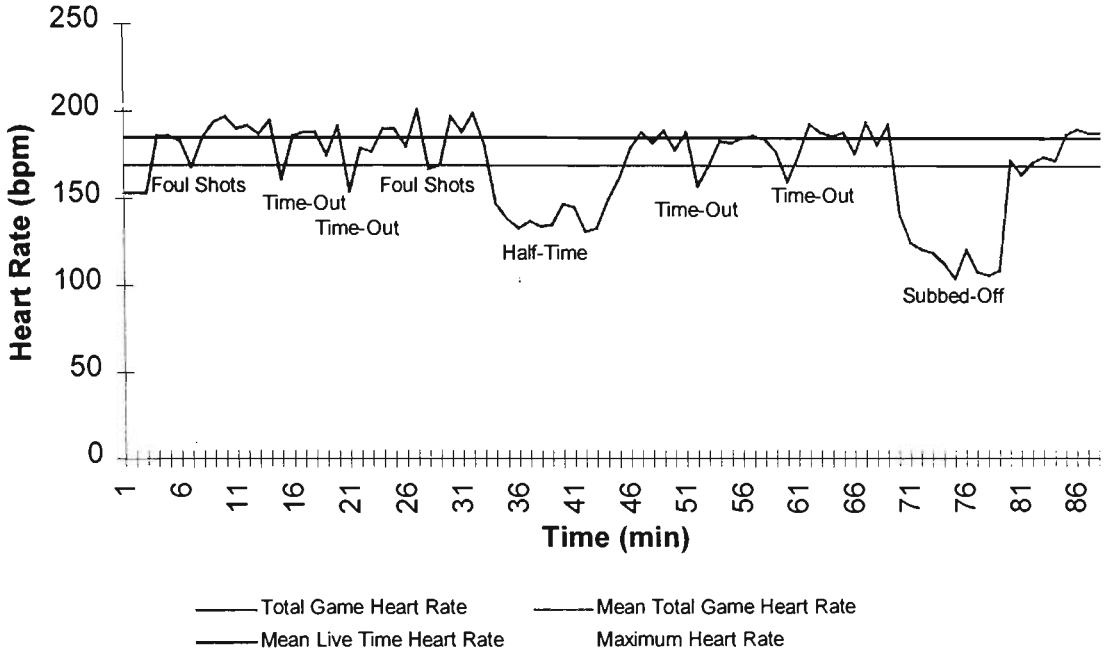
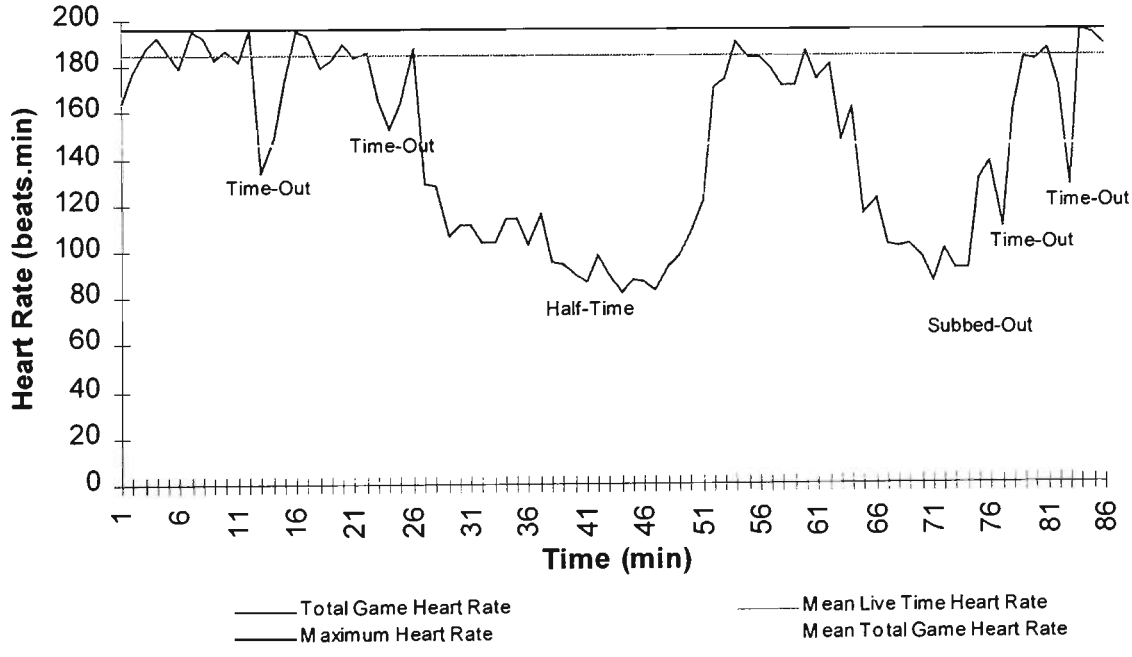


Figure 4.7: Heart Rate Response of Subject 3 (Centre) During Competitive Basketball Performance

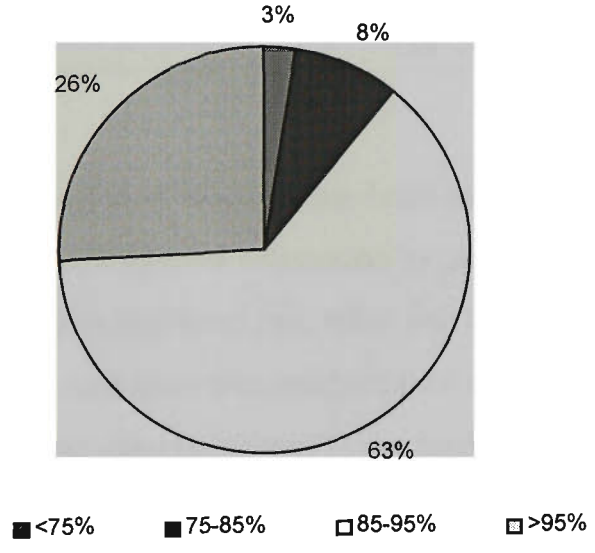


4.3.2 Absolute and Relative Heart Rate Zones

The intense nature of elite women's competitive basketball performance is again indicated in Figure 4.8, which breaks the live time heart rate values of the eight randomly selected players into heart rate zones.

Of the live time heart rate values, approximately 89% were found to represent percentages of intensity greater than 85% heart rate maximum (HR max), and approximately 63% of live time heart rate values were found to fall in between 85 - 95% of HR max. In addition, approximately 26% of live time heart rate values were found to be above 95% HR max.

Figure 4.8: Live Time Heart Rates Recorded During Elite Women's Basketball Performance and Expressed According to Heart Rate Zones



4.3.3 Blood Lactate Threshold

Lactate threshold heart rates of the eight randomly selected basketballers (3 guards, 3 forwards and 3 centres) were calculated during a discontinuous treadmill protocol with 3 minutes of running interrupted by 1 minute rest.

Blood lactate concentration was plotted against VO_2. Visual observation of a clear deflection point, i.e. the highest VO_2 before an observable elevation in blood lactate, was made by three independent and practiced researchers. The mean heart rate corresponding to this point was calculated. Individual live time heart rates were classified and sorted according to values found above and below the lactate threshold heart rate.

Table 4.9 indicates the level of intensity of elite women's competitive basketball performance with 94% of live time spent at a heart rate above lactate threshold heart rate.

Table 4.9: Percentage of Live Time Heart Rate Values of Eight Elite Women Basketballers Above and Below the Lactate Threshold and 4 mM Blood Lactate Concentrations During Competitive Performance

HR ($b.min^{-1}$) at LT	**% HR Live Time >LT**	**% HR Live Time < LT**	**HR ($b.min^{-1}$) at 4 mM**	**% HR Live Time >4 mM**	**% HR Live Time < 4 mM**
157 ± 4	94 ± 1	5 ± 1	168 ± 5	85 ± 4	15 ± 4

Mean ± SEM

Although controversial, the 4 mM blood lactate level was calculated during the same incremental treadmill test to volitional exhaustion by plotting blood lactate values against speed. The corresponding heart rate value was determined by identifying the speed in the test that the 4 mM level was reached, then extrapolating a heart rate value from the 'line of best-fit' between the means in the final minute of each incremental rise corresponding to the same speed.

When this method was used, 85.28% of the live time values during elite women's competitive basketball performance were found to be above the heart rate corresponding to a blood lactate value of 4 mM.

CHAPTER 5

DISCUSSION, SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 DISCUSSION

The discussion section of this chapter will detail the following major findings:

1. Positional differences in height and body mass.
2. Non positional differences in skinfold measurements.
3. Non positional differences in maximal effort data.
4. Positional differences in lactate threshold and ventilatory break point.
5. Non positional differences in absolute and relative heart rate intensities during competitive performance.
6. Intense nature of competitive performance according to relative heart rate zones.
7. Non positional differences in blood lactate concentrations during competitive performance.
8. Body mass deficits during competitive performance.

Each of the sections following will discuss the major findings, the similarities or differences that may have been found in relevant literature and possible explanations for the findings and their place in the literature.

5.1.1 Descriptive Data

The descriptive data in this study are an indication of the overall finding that relatively high percentile rankings for height and body mass appear to be pre-requisites for those basketball players who spend the majority of their time nearest the basket during competitive performance.

A comparison of these data was made with studies of other elite women's basketball squads. In the present study the basketballers were of similar height but heavier than internationally competitive women basketballers described by previous investigators (Carter, 1970; Eiben, 1981; Hakkinen, 1993; Spurgeon et al., 1980). Differences in body mass were in the order of 5 kg when compared to the collective means of the 214 players from eight international basketball playing nations. In addition, the present sample was also found to be of similar body mass but shorter (4.6 cm or 2.5%) than Canadian basketballers (Smith & Thomas, 1991) and of similar height and body mass to American college basketballers (Crouse et al., 1992).

A comparison of the overall group in the present study was also made with women athletes from sports other than basketball [Table 5.1]. In general, the present sample of basketballers were taller and heavier than in the studies profiling gymnasts (Conger & Mcnab, 1967; Sinning & Lindberg, 1972), hockey players (Ready & van der Merwe, 1986), soccer players (Colquhoun & Chad, 1986), swimmers (Cunningham & Eynon, 1973), tennis players (Buti et al., 1984; Vodak et al., 1980) and cross-country runners (Butts, 1982). They were, however, of similar height and weight to volleyballers (Puhl et al., 1982; Spence et al., 1980) and netballers (Bale & Hunt, 1986).

Table 5.1: Summary of the Height and Body Mass Measurements of Women Athletes From a Variety of Sports

Year	**Author**	**Subjects**	**Height (cm)**	**Body Mass (kg)**
1967	Conger and Macnab	College Gymnasts	163.0	57.9
1972	Sinning and Lindberg	College-Age Gymnasts	158.5	51.5
1973	Cunningham and Eynon	Young Competitive Swimmers (10-16 years of age)	164.8	53.7
1980	Vodak et al.	Highly Skilled Middle-Aged Tennis Players	163.3	55.7
1980	Spence et al.	Elite Volleyballers	183.7	73.4
1982	Butts	High School Cross-Country Runners	163.3	50.9
1982	Puhl et al.	Elite Volleyballers	178.3	70.5
1984	Buti et al.	Elite Pre-pubescent Tennis Players	150.9	42.9
1986	Bale and Hunt	Elite English Netballers	172.9	65.5
1986	Colquhoun and Chad	Elite Australian Soccer Players	158.1	55.4
1986	Ready and van der Merwe	Olympic Hockey Players	161.7	58.0
1991	Smith and Thomas	Elite Canadian National Team Basketballers	181.8	74.5
1991	Hakkinen	Elite Finnish Basketballers	176.0	69.6
1992	Crouse et al.	American College Basketballers	178.2	73.4
1998	Present Study	Elite Australian Basketballers	177.2	74.4
Mean				

For sports such as basketball, volleyball and netball, where the height of the net or ring is fixed, it is possible that above average height and body mass is beneficial to performance. Tall players need jump a lower relative percentage of their stature, in order to reach close to, or above the ring or net. Since a large proportion of the games of basketball, netball and volleyball are spent performing jumping movements, height would appear to be an advantage particularly to those players who spend the majority of their time closest to the net or ring. Players with a larger body mass are likely to be harder to shift in situations that involve jostling for position. This would seem particularly appropriate to basketball where players often find themselves using their bodies within the context of the game, to gain, for example, a solid rebounding or inside shooting position. Whilst it could be suggested that a player with a short stature and low body mass is likely to be disadvantaged in sports such as basketball, netball and volleyball, skill level and the position that such a player may fulfil on the court, may ultimately determine her success.

Positional differences in height and weight in the present study were compared with studies of similar investigation. The findings were similar to those of previous reports (Ackland et al., 1994; Smith & Thomas, 1991; Spurgeon et al., 1980). Their collective research with national level basketball players indicated that the centres were taller and heavier than the forwards and the forwards were taller and heavier than the guards.

The guards participating in the present study had a lower mean height (6.0 cm or 3.4%) than the guards participating in the investigation conducted by Smith and Thomas (1991). The difference in the mean height of the guards in this study and the research conducted by Ackland et al. (1994) was only 1.4 cm or 0.8%.

The present sample of guards had a slightly smaller mean body mass than the subjects participating in the investigation conducted by Smith and Thomas

(1991), (0.1 kg or 0.1%), but a slightly larger body mass than reported by Ackland et al. (1994), (1.1 kg or 1.7%).

The players who volunteered for the present study could be described as undertaking interchangeable forward/centre roles rather than having a discrete position on the court. Nevertheless, the mean height of the forwards/centres was slightly less than the mean height of the discrete power forwards (1.1 cm or 0.6%) reported by Smith and Thomas (1991). In addition, it was slightly higher than that of the discrete shooting forwards (2.6 cm or 1.4%) and smaller than the mean height of the centres (4.5 cm or 2.4%).

These findings were consistent with comparisons between the present study and data presented by Ackland et al. (1994). The mean height of the forwards/centres was 2.7 cm or 1.5% higher than the mean height of the forwards and 5.3 cm or 2.8% shorter than the mean height of the centres reported by Ackland et al. (1994).

In terms of body mass, the forwards/centres in the present study were 4.4 kg or 5.8% and 2.8 kg or 3.6% heavier respectively, than the power forwards and shooting forwards reported by Smith and Thomas (1991). They were also 5.3 kg or 7.0% and 2.1 kg or 2.7% heavier respectively, than the forwards and centres measured by Ackland et al. (1994).

A variety of other authors have investigated the height and body mass of elite women basketballers (Crouse et al., 1992; Hakkinen, 1993). Meaningful comparison between the findings of these researchers and the present study was not able to be made in terms of position, as the authors chose to report the mean height and mean body mass as an overall group mean.

The positional differences found in height and body mass in the present study, and the consistency of this finding with the current literature, may be

explained in terms of the subtle differences in the roles that the guards and forwards/centres have during competitive performance. Coaches of the modern game of women's basketball emphasise speed and power movements regardless of position. In general, the forwards/centres are likely to spend the majority of their time during offensive and defensive plays closer to the basket positioning for inside shooting and rebounding opportunities. With the exception of fast-break, one on one, and lay-up situations, the guards are more likely to spend the majority of their playing time in positions further away from the basket [Ray Tomlinson, *Personal Communication,* Coach of the Australian Junior Women's Team]. Therefore, it appears that height and body mass are more important for basketballers who play in the forward/centre position than for basketballers who play in the guard position.

5.1.2 Body Composition: Skinfold Measurements

The sum of five sites was used as an estimate of skinfold thickness in body composition. The skinfold data in the present study were reported as a sum of absolute values and ranged between 38.4 and 90.9 mm with a mean score of 62.2 mm for the sum of five sites.

Comparisons of the guards and forwards/centres in the present study revealed non-significant differences in four out of the five individual sites and the total sum of skinfolds. The one exception was the mid-abdomen skinfold site. This finding was in contrast to the research conducted by Smith and Thomas (1991) and Ackland et al. (1994) who measured the sum of skinfolds of the Canadian Women's Basketball Team and competitors from 14 nations at the 1994 World Basketball Championships, respectively. Smith and Thomas reported significant differences when the sum of skinfolds of the guards was compared to the shooting forwards and centres. Non-significant differences were found in the sum of skinfolds of the guards and the power forwards, the power forwards and the shooting forwards, the shooting forwards and the centres, and the power forwards and the centres.

Ackland et al. (1994) reported significant differences in the sum of skinfolds of the guards compared with the centres, and the sum of skinfolds of the forwards compared with the centres. The authors reported non-significant differences in the sum of skinfolds of the guards and the forwards.

The finding of no difference in the sum of skinfolds recorded by the guards and the forwards/centres in the present study may be explained by the collapsing of the forwards and centres into one group. It is possible that this offset any potential difference in the sum of skinfolds of the guards and the centres. The other possible explanation may lie in the emphasis that coaching staff placed on similar training regimes for all players. With coaches of the modern game demanding extended periods of speed and power movements regardless of position, fitness advisers working with subjects in the present study were prescribing similar strength and endurance programs for the guards, forwards and centres. Therefore, overall changes in the sum of skinfolds were likely to have shifted proportionally for all players regardless of position.

Despite a variety of skinfold research surrounding women's basketball (Ackland et al., 1994; Eiben, 1981; Hakkinen, 1993; Smith & Thomas, 1991), valid comparisons between these data and the results of the present study were unable to be made. This was due to difficulties created by the varying numbers and types of skinfold sites used. However, the sum of the skinfolds measured at the tricep, suprailiac, bicep and subscapular cited in a number of the investigations were able to be converted into body fat values using the Durnin and Womersley (1974) regression equation to estimate body density. These values were then compared with the data in the present study.

The percent body fat values for the guards, forwards/centres and the overall group were found to be 24.7%, 26.3% and 25.7%, respectively.
Lohman (1982) reported that the optimal range of body fat for adult females is 15%-25%, with 25%-30% classified as moderately high, 30%-35%

classified as high, and >35% classified as very high. Lohman (1982) indicated that the 15%-25% range allows for individual differences in physical activity and preferences, and is associated with little or no health risk due to diseases associated with fatness. This was consistent with the standards reported by Egger and Champion (1990). These authors stated percent body fat values less than 25% could be considered as 'acceptable' and values greater than 25% within the 'overweight' category for female athletes. However, given only a 1.6% difference in the body fat of the guards and forwards/centres in the present study, a classification of optimal for the guards and moderately high for the forwards/centres would seem inappropriate. A conclusion based on the results appearing either side of an arbitrary point seems to have little real meaning.

Furthermore, due to an inflated margin for error when converting the sum of skinfolds to a percent body fat value and the somewhat spurious comparison of these results with a population not necessarily relevant to basketball (Walsh, 1996), caution must be taken when interpreting these results.

Within the recognised limitations of comparative discussion of percent body fat values, the following observations were noted. The percent body fat value of 25.7% for the overall group in the present study was compared with the values reported by Crouse et al. (1992) and Hakkinen (1993). This value was 6.3%, 7.8% and 4.7% higher, respectively, than the values recorded by the American college basketballers measured during autumn, winter and spring by Crouse et al. (1992). It was also 0.6% and 0.2% less, respectively, than the values recorded by the elite Finnish basketballers measured by Hakkinen (1993) before and after a competitive season.

The percent body fat of the present sample of athletes was also found to be well in excess of the 11%-16% body fat values for the women runners, jumpers, divers and gymnasts measured during the Montreal (Carter 1982), Tokyo and Mexico (de Garay et al., 1974; Hirata, 1966) Olympic Games.

This difference, however, may be explained in the natural self-selection that occurs in the fundamental characteristics of the sports. Gymnastics in particular could be described as predominantly propulsive in nature. That is, the muscles required for propulsion need to be well developed whereas the non-propulsive mass (fat mass and other muscle groups) needs to be minimised in order to attain maximal speed and power. In sports that require speed and explosive power, increases in body mass in the form of excess fat may decrease acceleration unless increases in force are applied (Norton & Olds, 1996). Whilst this is probably true for basketball, the extent to which performance would be negatively affected by increased fat mass in sports such as gymnastics, jumping and diving is likely to be greater as such sports rely, to a larger extent, on propulsive movements.

The development of a range of expected sum of skinfold and percent body fat values specific to women's basketball would seem useful for coaches and sports scientists to ascertain. Constructing player profiles in the form of normative data can be particularly useful in establishing training targets and developing training programs specific to basketball. However, the extent to which athletes of a particular body composition are drawn, rather than lead, to the sport of basketball forms an interesting question that is beyond the scope of this research.

Of particular interest is that while average values for body composition are clearly different among sports, for athletes within a particular sport there is rarely a high correlation between body composition and performance (Bar et al., 1994). Despite not providing evidence, these authors contended that there were no data from controlled studies to suggest that manipulations of body composition, independent of other factors, leads to anticipated changes in performance. Based on this suggestion, it would appear that skinfold comparisons of individual basketballers as a method of team selection or as a means of talent identification could be considered inaccurate, unjust, and unfair.

Therefore, it would appear that there is a substantial need for further investigation into the skinfold and percent body fat values of women basketballers. In particular, research in this area should consider whether changes in body composition will in fact impact on basketball performance and whether establishing an 'ideal' sum of skinfolds or percent body fat range for elite women basketballers is an appropriate or desirable task.

5.1.3 Maximal Effort Data

In the present study, no difference in the relative maximal oxygen consumption of the guards and forwards/centres was observed. A summary of the data pointed to homogeneity among the participating positional groups. Comparisons with studies using the same maximal aerobic power test revealed a consistency in results with only minimal differences being observed.

The value of 49.5 $ml.kg^{-1}.min^{-1}$ recorded by the guards was less than the VO_2 max of the guards in the National Canadian Women's Basketball Team (4.8 $ml.kg^{-1}.min^{-1}$ difference or 8.9%) reported by Smith and Thomas (1991). The value of 48.3 $ml.kg^{-1}.min^{-1}$ recorded by the forwards/centres was less than the power forwards (2.4 $ml.kg^{-1}.min^{-1}$ difference or 4.7%), greater than the shooting forwards (1.3 $ml.kg^{-1}.min^{-1}$ difference or 2.8%) and less than the centres (2.6 $ml.kg^{-1}.min^{-1}$ difference or 5.1%) when compared with the National Canadian Women's Basketball Team reported by Smith and Thomas (1991).

In contrast to the present study, Smith and Thomas (1991) reported significant differences in the values recorded by the guards and the shooting forwards but no difference in the values recorded by the guards, power forwards and centres - despite the latter two groups averaging slightly lower values than the guards (3.6 and 3.4 $ml.kg^{-1}.min^{-1}$, respectively). The

closeness in the VO_2 max values of the guards and forwards/centres in the present study is likely to reflect changes in the style of the elite women's game of basketball and the training protocols over recent years.

In Australia today, players with potential have greater opportunities to access high level coaching than past players. This is due to the introduction of coaching programs at the National and State level, such as those offered by the Australian Institute of Sport (AIS) and Victorian Institute of Sport (VIS), together with the establishment of junior programs (National, State and Club level). Consequently, today's women basketballers have a greater level of skill, are more versatile and better prepared physically (Ray Tomlinson, *Personal Communication,* Coach of the Australian Junior Women's Team). With offenses now structured to reflect the versatility of players - guards, forwards and centres find themselves in a variety of positions at different times of the game. To prepare the present sample of athletes for the modern game, conditioning training prescribed by fitness and conditioning professionals emphasised the same high intensity endurance running, swimming and cycling for all players. Therefore, training responses over time are likely to have contributed to the closeness in VO_2 max scores in the present study, with such values shifting proportionally regardless of position.

The overall group value in the present study of 48.88 $ml.kg^{-1}.min^{-1}$ was similar to the combined group mean of the college basketball teams measured by McArdle et al. (1971), Riezebos et al. (1983) and Vaccaro et al. (1979), and only 1.27 $ml.kg^{-1}.min^{-1}$ or 2.5% less than the mean VO_2 max of the Senior Australian Women's Basketball Team between 1993 and 1996.

This value was also found to be 4.98 $ml.kg^{-1}.min^{-1}$ or 11.98%, 4.78 $ml.kg^{-1}.min^{-1}$ or 10.84% and 5.98 $ml.kg^{-1}.min^{-1}$ or 13.94% higher, respectively, than the VO_2 max values of college basketballers reported by Crouse et al. (1992) during fall, winter and spring. However, the mean from the present study

was only 0.88 ml.kg^{-1}.min^{-1} or 1.83% and 1.88 ml.kg^{-1}.min^{-1} or 4.0% higher, respectively, than the mean VO_2 max of the elite Finnish basketballers measured by Hakkinen (1993) before and after a competitive season. Comparisons between the present study and that performed by Hakkinen (1993) need to be interpreted with caution, as the latter investigation involved the use of a cycle ergometer test to determine VO_2 max in preference to a treadmill running protocol.

A comparison of the overall group in the present study was also made with women athletes from other intermittent sports. In general, the present sample of basketballers had a VO_2 max similar to the women soccer players measured by Colquhoun and Chad (1986), Evangelista et al. (1992) and Rhodes and Mosher (1992) who reported values of 47.9, 49.8 and 47.1 ml.kg^{-1}.min^{-1}, respectively. The value of the present sample of athletes was also compared with the elite women hockey players measured by Rate and Pyke (1978) and Walsh (1996) who reported VO_2 max values of 50.1 and 51.8 ml.kg^{-1}.min^{-1}, respectively. These were slightly higher than the value recorded by the overall group in the present study.

Based on these findings and those analysing the demands of the game, it is clear that the subjects tested were in an elite class when compared to published data on basketballers and other intermittent team sport players. In addition, it appears that the elite woman basketball player requires a high level of aerobic endurance.

5.1.4 Lactate Threshold and Ventilatory Break Point

5.1.4.1 Lactate Threshold and Ventilatory Break Point Profile Data

The present study used both blood lactate and gas exchange variables to determine the submaximal performance markers of lactate threshold and ventilatory break point, respectively. Differences were found in the lactate threshold and ventilatory break point of the guards and the forwards/centres.

The lactate threshold of the guards occurred at a mean speed of 12 $km.hr^{-1}$ whereas the lactate threshold of the forwards/centres occurred at a mean speed of 10 $km.hr^{-1}$ [Figure 4.2]. This was supported by the finding that the ventilatory break point for the guards occurred further into a test to volitional exhaustion than that of the forwards/centres [Table 4.5]. This would appear to be a considerable finding given that exercise intensity at the lactate threshold and ventilatory break point have been shown to be an important factor influencing endurance performance (Farrell et al., 1979; Fay et al., 1989; Kumagi et al., 1982 and Tanaka et al., 1983). It suggests an advantage in prolonged aerobic metabolism (from absolute data) in the guards when compared with the forwards/centres.

Since the groups recorded non-significant differences in maximal blood lactate concentration and VO_2 max, it would appear that positional differences in the present study were more readily identified submaximally. As all players were involved in the same training program both prior to and during testing, differences in the training state of the players was eliminated as a possible cause of the submaximal variance. One possible explanation, however, may be differences in the muscle fibre distribution of the athletes who predominantly play in different positions on the basketball court. It has been demonstrated that slow-twitch fibres have a higher respiratory capacity than fast-twitch fibres (Gollnick & Hermansen, 1973). It is possible that based on generic 'on-court' positional differences that elite basketball attracts

smaller and aerobically fitter players to the guard position. Differences in fibre typing was beyond the scope of the current research. Consequently, further exploration into muscle fibre configuration contributing to positional differences is recommended. In addition, Ivy et al. (1980) reported that the percentage of slow-twitch to fast-twitch fibres may exert a genetic influence over lactate threshold and could influence the degree to which the relative threshold can shift. Therefore, the lactate threshold might be a high predictor of aerobic ability both before and after training.

A further possible explanation of submaximal differences may rest with the running economy of players. Cavanagh and Kram (1985) reported that there was an optimum combination of stride length and frequency that was largely dependent on an individual's style of running and this optimum can not be determined accurately from body measurements. Given that a runner who is uneconomical will expend a greater amount of energy to run at a given speed than an efficient runner, it is possible that the guards in the present study were more economical at lower speeds than the forwards/centres. Participants in the present study were encouraged to select their own stride length. This has been suggested as the best procedure as it produces the most economical running performance when taking into account individual variations in body mass, inertia of limb segments, and anatomical development (Cavanagh & Kram, 1985; Heinert et al., 1988). Given that running economy was not investigated this possibility remains speculative.

Comparative data on positional differences at varying submaximal running speeds were difficult to obtain. Positional differences in lactate threshold and ventilatory break point were able to be compared to the differences observed in Danish national soccer players as reported by Bangsbo (1993). By testing elite male players during treadmill-running, it was revealed that a given blood lactate concentration was obtained at a higher VO_2 for midfield players than for central defenders and goalkeepers. This may be explained by the difference in the roles that these positional players were expected to fulfil.

Because midfielders were the link between defenders and forwards, they covered longer distances during a match than any other player (Ekblom, 1986; Reilly & Thomas, 1976; Withers et al., 1982). Whilst no difference existed in high speed running between groups, midfielders were expected to perform more sustained activity in the form of jogging and low speed running. Whilst the calculation of distances covered by women basketballers playing different positions was beyond the scope of the present study, it is possible that differences in exercise performances due to 'on-court' training experiences may have contributed to the results observed in the present study.

5.1.4.2 Relevance of Ventilatory Break Point to Competitive Basketball Performance

Despite differences in the time that a ventilatory break point was observed for the positional groups in the present study, no difference was found in the absolute heart rates at which this point was observed. In addition, non-significant differences were reported in the heart rates when they were expressed as a percentage of heart rate maximum. Ventilatory break point occurred at a heart rate of 183 $b.min^{-1}$ or 95% of heart rate maximum for the overall group [Table 4.5].

Live time heart rate values were classified according to lactate threshold. Seventy-four percent of live time during competitive performance was found to occur at a heart rate less than ventilatory break point [Figure 4.8]. This finding appeared to suggest that if ventilatory break point was used as the basis for deciding the relative energy contribution to elite basketball performance, then elite women's basketball would be classified as predominantly aerobic in nature. However, for reasons outlined in the following paragraphs, this classification is refuted.

5.1.4.3 Relevance of Lactate Threshold to Competitive Basketball Performance

The present study reported differences in the speeds at which a lactate threshold was observed for the guards and the forwards/centres during a discontinuous treadmill test (3 minutes activity interspersed with 1 minute break) to volitional exhaustion [Figure 4.2]. Despite this finding, no difference was found in the heart rates at which the lactate threshold was observed for both groups or in the heart rates when expressed as a percentage of heart rate maximum. In the present study, lactate threshold occurred at a heart rate of 157 $b.min^{-1}$ or 81% HR max [Table 4.9]. When live time heart rate values recorded during competitive basketball performance were classified according to lactate threshold, 94% of live time was found to occur at a heart rate above the heart rate corresponding to lactate threshold [Table 4.9]. Furthermore, 63% of live time was found to be spent at a heart rate between 85 and 95% of HR max (4 to 14% above lactate threshold) and 26% of live time elicited heart rates above 95% of HR max. This left only 11% of live time being spent at a heart rate either close to or less than the heart rate corresponding to the lactate threshold [Figure 4.8].

The results from the present study appeared to suggest that if lactate threshold is used as the basis for deciding the relative energy contribution to elite basketball performance, then elite women's basketball would be classified as predominantly anaerobic in nature. However, with activity above lactate threshold there is still significant aerobic metabolism underpinning effort making this a difficult conclusion to argue. Furthermore, heart rate measures taken during an incremental exhaustive test are not easily related to high intensity, intermittent efforts. For example, heart rates recorded during a 10 second effort at 100%, 140% and 180% VO_2 max may be quite similar, yet clearly exercise intensity and anaerobic metabolism will be very different. Perhaps the number and duration of supramaximal

anaerobic efforts may have been a more relevant point of investigation, but unfortunately it was beyond the scope of this research.

The exact cause of the anaerobic threshold is controversial and has been the subject of many review papers in recent times (Davis, 1985; Jones & Ehrsam, 1982; Powers & Beadle, 1985; Skinner & McLellan, 1980; Wasserman et al., 1981). In addition, at no point in the literature are threshold measures used to proportion energy system contributions, particularly during high intensity intermittent exercise. Thresholds are generally related to continuous exercise and endurance parameters. Subsequently, threshold measures would appear inappropriate in determining the relative energy contribution to elite women's basketball. Consequently, the debate emerges as to the proportion of time that might be spent training at high intensities.

The intermittent nature of the energy contribution in basketball tends to highlight the importance of high intensity training. Furthermore, the reliance of the game on extended and repeated speed and agility movements during offensive and defensive play tends to infer that high intensity interval training should subsume a high proportion of the endurance training program. The aerobic system would appear important, however, in recovery from sprint efforts in terms of phosphate creatine replenishment.

High intensity interval training has been shown to impose intensive stimuli to both anaerobic and aerobic energy supplies with continuous training limited to the development of aerobic energy supplies (Tabata et al., 1996; Overend et al., 1992). However, continuous training at or above the lactate threshold may be effectively used during the early phase of a training program. Weltman et al. (1992) reported that these intensities produce similar improvements in VO_2, velocity at the lactate threshold and fixed blood lactate concentrations of 2.0 and 2.5 mM during the first few months of training. This technique may be relevant when prescribing training for players who have incurred lengthy periods away from training or for those players with

less than desirable pre-training fitness levels. For continued improvement beyond the initial stages, however, training above the lactate threshold should be prescribed (Weltman et al., 1992).

5.1.5 Absolute and Relative Heart Rate Intensities

Heart rate data used to indicate field intensity was collected using a portable heart rate monitoring system (Polar Sports Tester™) during competitive basketball performance. The major finding from these data was that no differences were reported in the mean live time and total game heart rate values recorded by the guards and forwards/centres in the present study. There was an additional lack of difference when absolute heart rate values were expressed as a relative percentage of maximum heart rate.

Large variations in mean total game and mean live time heart rate values were not expected, despite the likelihood of variations in the movement patterns of guards, forwards and centres, throughout a game. The lack of difference in mean heart rate values between traditional court positions may be due to poor sensitivity of heart rates to subtle differences in submaximal intensity under varying emotional conditions. Differences in heart rates could also be difficult to detect, given that the subjects participating in the present study all received similar amounts of court-time and all covered the full-length of the court.

Very little literature exists which has examined the absolute and relative heart rate values during competitive basketball performance. McArdle et al. (1971) reported relatively high game intensities in adult women basketballers during a season of college matches (81-95% HR max.). The authors (1971) reported that the position of guard was the most strenuous. The playing heart rates of the guards averaged 192 $b.min^{-1}$ during time on court. This represented 94% of HR max. Similarly, the present study reported a mean total game heart rate equivalent to 80% of HR max. and a mean live time heart rate equivalent

to 91% of HR max for the overall group. The fact that the guards averaged higher mean live time heart rates than the forwards and the centres in the study conducted by McArdle et al. (1971), may be explained by the differences in the modern style of game and the style of women's basketball 25 years ago. It is very likely that the guards measured by McArdle et al. (1971) were the players primarily responsible for bringing the ball up the court in attack and putting pressure on opposition guards in defense. Therefore, they were required to perform highly intense movements for the majority of their time on court. It was primarily the responsibility of the forwards and centres to establish shooting and rebounding positions inside the key. These players were very rarely involved in bringing the ball up the court or full-court defense [Ray Tomlinson, *Personal Communication,* Coach of the Australian Junior Women's Team]. Whilst this general philosophy is still a part of the modern game, it is generally accepted that players today have a higher level of skill and fitness [Lori Chizik, *Personal Communication,* Assistant Coach Australian Women's Basketball Team]. Therefore, forwards and centres may also expected to play a role in bringing the ball up the court in attack and playing full-court defense.

Despite the likelihood of differences in style of play, the heart rate data in the present study was compared with the data of the elite Australian male basketballers reported by McInnes (1993). The author reported a mean live time heart rate of 168 $b.min^{-1}$ which was 9 $b.min^{-1}$ lower than the value recorded by the players in the present study. Similarly, the relative live time heart rate value of 89% for the males was 3% less than the relative live time heart value of the present sample of women athletes. Based on mean absolute and relative heart rate data, it would appear possible that the women's game of basketball is played at a higher intensity than the male game. However, the limited number of studies investigating heart rate data during male and female performance does not allow accurate conclusions to be drawn.

Despite a limited number of studies investigating the relative and absolute heart rate intensities of women's basketball, comparisons of the present study were made with investigations involving other intermittent team sports. The mean live time heart rate of 177 $b.min^{-1}$ in the present study was comparable to the study of all-female soccer teams by Miles et al. (1992). The authors (1992) reported a mean live time heart rate of 176 $b.min^{-1}$. This value was also similar to the findings of Ekblom and Aginger (unpublished data) who reported mean live time values of 177, 174 and 173 $b.min^{-1}$ in three separate full-sided female soccer games. In addition, the mean live time heart rate value in the present study was similar to the value reported by Astrand and Rodahl (1977) who measured international female hockey players (180 $b.min^{-1}$). It was higher than the mean value (157 $\pm$ 15 $b.min^{-1}$, 85% of HR max) for elite women Australian hockey players reported by Walsh (1996). However, relative intensity comparisons were unable to be made with the majority of these studies as the authors did not report maximum heart rate values.

5.1.6 Relative Heart Rate Intensities Expressed According to Heart Rate Zones

The intense nature of elite women's basketball is demonstrated in the finding of the present study that a majority (89%) of the live time heart rates were above 85% HR max [Figure 4.8]. Furthermore, 26% of live time heart rate values were found to be above 95% HR max. and 63% were found to occur between 85 and 95% HR max.

Inter-study comparisons should be interpreted with caution due to obvious differences in sample size and methodologies. However, the findings of the present study were compared with the research of Woolford and Angove (1991) who examined the heart rates of the South Australian Senior Netball Team leading up to, and during, the 1990 National Titles. The centre position in netball is reported to place the greatest physiological demand on players (Woolford & Angove, 1991) as these players incur the least amount

of movement restriction. It is likely that the movements of the centre position are more likely to resemble basketball than any other netball position. Therefore, comparisons of players in the present study were made with the netball centres in the research conducted by Woolford and Angove (1991).

Similar to the present study, Woolford and Angove (1991) reported that a high percentage (75%) of total playing time (excluding warm-up time, time-outs during play and breaks between quarters) for the netball centres was spent at a heart rate above 85% HR max. In addition, the authors reported that 26% of total playing time (excluding warm-up time, time-outs during play and breaks between quarters) was spent at a heart rate greater than 95% HR max which was similar to the present study. The smallest percentage of time during netball (25%) was spent at a heart rate less than 85% HR max.

The major differences in the results in the present study and in the research conducted by Woolford and Angove (1991) were found in Zone 2 and Zone 4 (based on definitions by Davis, 1996). The present sample of basketballers were found to spend a greater proportion of time in Zone 2 (85 to 95% of HR max.) and less time in Zone 4 (<75% HR max) than the centre players measured by Woolford and Angove (1991). Overall the basketballers spent a higher proportion of time at a heart rate above 85%. This would suggest that the elite woman basketballer needs to be conditioned to perform at high intensities for somewhat greater durations than the elite woman netballer.

This difference may be attributed to variations in the rules of the two sports. With netball centres permitted in all segments of the court bar the goal circle, it is quite possible that a certain proportion of live time for these players is spent at a lower heart rate after the ball has been delivered to the attacking players to score. This is in contrast to basketball, where all players are permitted in all segments of the court and are expected to either make themselves available to score or rebound at both ends of the court. Thus

basketball could be described as requiring intense efforts both inside and outside the key. The similarity in the percentage of time spent either at or above 95% HR max, suggests that netball centres and basketballers spend approximately the same proportion of time during competitive matches performing highly intense movements eliciting a response approaching maximal oxygen consumption.

The results in the present study were also compared with the heart rates of elite male hockey players competing at the Australian Men's Senior Championships and in domestic Division 1 competition (Cibich, 1991). The author reported that the right inner, striker, and backline players spent approximately 28% of total playing time above 92% of HR max. This was similar to the 26% of live time heart rates that the basketballers in the present study spent above 95% HR max.

The players in the study conducted by Cibich (1991) spent less time, however, at a heart rate greater than 85% of HR max when compared with the players in the present study (61% compared with 89%). These figures were similar to findings of Smodlaka (1978) and Walsh (1996). Smodlaka (1978) reported that heart rates of elite male soccer players recorded during competitive performances were above 75% HR max for approximately two-thirds of the game. Walsh (1996) measured elite women Australian hockey players during competitive performance and reported that 60% of playing time was spent at a heart rate in excess of 85% HR max.

It is again likely that the difference in the heart rate data recorded by players in the present study and that of the players measured by Cibich (1991) and Walsh (1996) was due to positional differences in the two sports. Unlike basketball, each of the four positions (back, centre half, inner & striker) measured by Cibich (1991) were likely to be restricted to moving within a zone equivalent to three-quarters of a hockey field in any given match. Depending on the nature of the game, the time that the ball was beyond the

playing zone of the player being measured was likely to be spent at a lower heart rate intensity. This would suggest that the elite woman basketballer needs to be conditioned to perform at high intensities for somewhat greater durations than the elite male hockey player.

Despite very little literature on the heart rate values recorded during competitive basketball performance, the presentation of the relative heart rate values into heart rate zones would seem most useful. Further significance of these intensity zones can be obtained from their relationships to Lactate Threshold (LT). Studies conducted on a variety of athletes by the South Australian Sports Institute (SASI) have demonstrated that an athlete's LT occurs at approximately 75% HR max and that the IAT occurs between 85 and 95% HR max. Heart rates above 95% HR max, have also been suggested to be indicative of maximal oxygen consumption [Woolford & Angove (1991)] and are thus reflective of highly intensive demands in a specific sport.

Training in any one of these zones is likely to result in different physiological adaptations. Zone 4 generally being prescribed for recovery and regeneration, Zone 3 for the development of the aerobic system, Zone 2 for the development of anaerobic threshold and maximal aerobic capacity and Zone 1 to improve an athlete's maximal anaerobic and aerobic capacity and speed (Davis, 1996). The findings of the present study suggest that intermittent team sports, and in particular women's basketball, are played at high intensities. The classification of elite women's basketball according to heart rate zones would further indicate that high intensity interval training should form a large proportion of the conditioning program of these athletes.

5.1.7 Blood Lactate Concentrations

The intense nature of elite women's basketball is again demonstrated in the present study by the level of blood lactate concentration observed throughout competitive performance [Figure 4.3]. The major finding was that the mean blood lactate value recorded ten minutes into the first half was higher than the mean values recorded at other stages of the game.

One possible reason for this difference might be the motivational level of the players following an extensive preparation leading into the commencement of the match. This may also explain the fact that the highest relative perceived exertion (RPE) value, on average, was also recorded at the time that the ten minute blood lactate concentration was taken [Figure 4.4]. With the likelihood of motivational benefits to players, consideration should therefore be given, by coaches, to the introduction of a structured preparation strategy in the warm-up prior to the start of the game and the commencement of the second half of play.

The present study also found that three out of the four lactate values measured during the game were found to be higher than the pre-game value. The one exception to this trend was that the mean full-time value was not different from the pre-game value. These findings were similar to the results of Ekblom (1986), Gerish et al. (1988), Rhode and Espersen (1988) and Smaros (1980) who reported that blood lactate concentrations recorded during the second half of elite male soccer performance were lower than blood lactate concentrations recorded in the first half. Bangsbo (1993) suggested that lower work to rest ratios at the completion of the game may result from reduced glycolytic activity caused by predictable game results and/or lower muscle glycogen concentrations. This explanation was supported by Walsh (1996) who reported lower lactate levels at the end of each half of elite women's field hockey. The calculation of work to rest ratios was beyond the scope of this study. The RPE results in the present

study [Figure 4.4] indicated that the perceived effort of players towards the end of the game was similar to the perceived effort in the first ten minutes of the game. Therefore, decreased effort caused by predictable game results seems an unlikely reason for lower blood lactate concentrations at the end of the game.

The type of fatigue that occurs during prolonged intermittent exercise may in fact be related to a depletion in muscle glycogen (Essen, 1978). The author suggested that the muscle fibres most frequently recruited and that have the lowest capacity to rebuild glycogen may be depleted. Soccer and basketball are arguably examples of sports that require prolonged intermittent exercise. Therefore, it is probable that reduced glycolytic activity and lower muscle glycogen could be the reason for the significantly lower full-time blood lactate concentration in elite women's basketball. However, research to date, remains speculative about the precise physiological mechanisms that elicit fatigue.

Intense exercise has been associated with the production of lactate and an elevated level of acidity within the muscles. Low pH has been shown to have an inhibitory effect on various functions within the muscle cell (Chasiotis, 1983; Cooke and Pate, 1990; Danforth, 1965; Donaldson et al., 1978; Edman, 1992). Whilst authors have reported that lactic acid accumulation and low pH can contribute to fatigue (Sahlin, 1986), these may not be the only determinants.

McKenna et al. (1996) reported that changes in intracellular and extracellular ion concentrations effect muscle function and contribute to the development of muscular fatigue during intense exercise. In addition, mental and physical fatigue may exacerbate the lower blood lactate concentration at the end of the game, with players saving their efforts for critical situations. Further differences in the physiological responses during the first and second halves of women's basketball may have been found if the present study obtained

information about the distances covered and the type of activity performed. This could have been demonstrated by data describing the movement patterns of players, their frequency and their duration. Future investigations should be conducted to determine answers to questions such as: Does the lower blood lactate concentrations in the second half correspond with a decrease in distance covered? Does the speed of the player's movements at the end of the game decrease? Do lower blood lactate concentrations at the completion of the game correspond with decreased muscle pH, and glycogen levels or changes in the activity of the sodium/potassium pump?

Large variations in blood lactate concentrations have been reported in intermittent team sports such as soccer (Ekblom, 1986; Gerisch et al., 1988), rugby (McClean, 1991) and field hockey (Walsh, 1996). This may be due to the unpredictable nature of these sports that produce sporadic involvement of players throughout the game and, in particular, immediately prior to blood sampling.

Lactate values of 5.1 $\pm$ 2.1 and 4.6 $\pm$ 2.1 mM, respectively, have been reported during the first and second halves of elite female soccer [Ekblom and Aginger (unpublished data)]. The investigators indicated that while glycolysis makes a significant contribution to the energy pool during a game, female players may not tax the anaerobic energy systems as highly as male players. This may also be true for basketball, as McInnes (1993) recorded a mean blood lactate concentration of 6.8 $\pm$ 2.8 mM for eight elite male basketballers during competition. This value was 1.1 mM or 19.3% greater than the mean blood lactate concentration of the women measured in the present study. However, the very limited number of investigations into blood lactate concentrations during both female and male basketball performances does not allow accurate conclusions to be made. Hence, further investigation in this area would seem appropriate.

Lactate is one of the end products of glycolysis. Therefore, blood lactate values can be a crude indicator that glycolysis has been activated (Balsom et al., 1992). Furthermore, the concentration of lactate in the blood is the balance of entry into the blood from muscle and removal from the blood by tissues such as the liver (Brooks, 1985). The increases in blood lactate concentration during the elite women's game compared to rest, suggest that glycolysis is an important energy source during competitive basketball performance.

5.1.8 Sweat Loss

Sweat loss was estimated from changes in pre and post game body mass. Players who participated in the monitored games did not consume enough fluid to maintain their pre-game weight, despite consuming a mean of 1.0 litres of fluid throughout the games. On average, players decreased 0.2 kg (0.2%) in body mass, resulting in an estimated overall sweat loss of 1.1 litres (1.5% body mass).

Overall sweat loss in the present study was within the range of values recorded by elite male soccer players but significantly less than the highest values observed (Hawley et al., 1994; Maughan, 1992). The authors (Hawley et al., 1994; Maughan, 1992) recorded sweat loss values of between 0.9 and 5 litres. This range of loss was dependent upon environmental conditions.

Body mass loss in the present study was less than the decrease of 3.1% and 1.2% observed for elite male soccer players during games at air temperatures and humidities of 33^{0}C and 40% and 13.2^{0}C and 7%, respectively (Mustafa & Mahmoud, 1979). In the present study the mean stadium temperature during data collection was 20°C $\pm$ 2°C with a mean relative humidity of 50%. Therefore in these thermoneutral conditions extreme body mass loss was not expected.

The body mass changes in the present study were also compared with the findings of Broad et al. (1996) who estimated fluid losses in elite team sport players during competitive performance [Table 5.2]. The 0.2% decrease in body mass in the present study was less than the values reported by the authors for elite women basketballers, netballers and soccer players. However, the latter study involved testing in temperatures above and below those used in the present study in a strategic effort to compare responses during summer and winter.

Table 5.2: Dehydration of Team Sport Players During Competitive Performance in Summer Versus Winter (Adapted from Broad et al., 1996)

Team Sport	%DH Summer	%DH Winter
Basketball	.7	.7
Soccer	1.2	-
Netball	.9	.3

Dehydration (%DH) = (body weight change - urine output) / initial body weight x 100

Broad et al. (1996) reported that dehydration in summer was not consistently greater than in winter for indoor team sports (netball and basketball). The authors concluded that athletes do not respond predictably or sensitively to environmental conditions to meet their fluid needs during physical activity. Therefore, fluid intake should be taught and encouraged rather than expected to be a spontaneous action.

The 1.1 litres estimated as mean sweat loss during the present study was 0.9 litres less than the decrease in body fluid of male soccer players during competitive performance under normal weather conditions as reported by Saltin (1964). In addition to differences in body size, one explanation for this variation may lie in the differences in the barriers to players in achieving adequate fluid intakes. In soccer, the rules of the game limit opportunities to drink. A match generally involves two 45 minute halves during which time drinks are not permitted on the field. Basketball players, however, are

provided with opportunities to drink during time-outs, between halves and during substitutions.

Dehydration negatively impairs physical performance, muscular endurance, mental functioning, thermoregulation and gastric emptying (Buskirk & Phul, 1989; Sawka and Pandolf, 1990; Williams, 1985). A 2% body mass loss has been associated with progressive performance decreases during high-intensity exercise (Ekblom, 1986; Walsh et al., 1994). Furthermore, a 30% performance decrement has been reported to correspond with a body mass loss of 5-6% (Saltin & Costill, 1988).

The basketballers in the present study were able to replace 86% of their sweat losses during competition. This was greater than the 50-75% for the basketball and netball players and the 49-54% for the women soccer players reported by Broad et al. (1996). This finding again may indicate differences in the barriers to players in achieving adequate fluid intakes. As previously reported, netballers and soccer players receive fewer drinking opportunities as a consequence of rules governing the sports. The higher sweat loss replacement value of the athletes in the present study may have been enhanced by the introduction of a dietary education strategy prior to the commencement of the season. In addition, players participating in the present study have played significantly more games at the national (Women's National Basketball League) and international level than the athletes tested by Broad et al. (1996). Ninety percent of the subjects in the present study were Australian Institute of Sport graduates and/or had previous experience with Australian Teams. Therefore, it is possible that this group of players had greater access over several years to fluid intake education than the athletes measured by Broad et al. (1996).

The value of increasing fluid intake during competition in an attempt to maintain full hydration is well documented (Mountain & Coyle, 1992; Walsh et al., 1994). Mountain & Coyle (1992) reported that fluid intake during

exercise was associated with greater cardiac output, greater skin blood flow, lower core body temperature and a reduced rating of perceived exertion. The authors suggested benefits could be optimised by replacing 80% of sweat loss during exercise.

Increased fluid intake during competitive performance can be useful in supplying the body with carbohydrates. Due to the fact that low muscle glycogen concentrations at the end of a match may impact on performance, intakes of carbohydrate solutions before and during a match may positively impact on performance (Kirkendall et al., 1988; Leatt & Jacob, 1989). Although more research needs to be completed, recent investigations have indicated performance benefits in terms of delayed fatigue from carbohydrate ingestion during intermittent exercise (Jackson et al., 1995; Nicholas et al., 1996; Vergauwen et al., 1996). This was further supported by Broad et al. (1996) who stated that carbohydrate supplementation has been shown to improve performance in team sports where matches last 90 minutes or more (including warm-up). However, in a study which examined carbohydrate loading and associated metabolic responses, Tarnopolsky et al. (1995) suggested that women do not respond as well to carbohydrate loading as their male counterparts.

In general, the findings of the present study support the recommendations of Broad et al. (1996) that the general intake goal for women basketballers should be 600 to 1000 $ml.hr^{-1}$. However, further studies examining the optimal concentration of carbohydrate, electrolyte content, volume, temperature, and frequency of ingestion for elite women's basketball performance should be conducted. Given the inherent benefits to performance, particularly during national and international competitions, this would appear to be crucial to the future improvement of the standard of basketball.

5.2 SUMMARY

5.2.1 Anthropometric Profile

The descriptive data indicated positional differences in the height and body mass of elite women basketballers. It should be noted that forwards/centres, who spend the majority of their time closest to the basket during games, recorded greater height and body mass values than guards. This finding, which was consistent with other studies in the literature, may be explained by differences in the roles that the guards, forwards and centres have during competitive performance. In addition descriptive data indicated that elite women basketballers were taller and heavier than elite female athletes from a range of other court and field-based intermittent sports. This perhaps best describes part of the 'natural' selection of the sports, particularly at the elite level. Greater height and body mass could be an advantage in basketball manoeuvres associated with power such as when jostling for shooting and rebounding opportunities.

Skinfold measurements revealed non-significant differences between positions in four out of the five individual sites and the total sum of skinfolds. Other studies in the literature reported positional differences in the sum of skinfolds for women basketballers. The findings of the present study may be attributed to two possible causes. Firstly, the decision to collapse the forwards and centres into one group. Secondly, the greater emphasis of modern coaches on similar training regimes for all players. A comparison of the present study with the plethora of skinfold research surrounding women's basketball was unable to be made. This was due to difficulties created by varying numbers and types of skinfold sites used. Within the recognised limitations of comparative discussion of percent body fat values, women basketballers were found to possess greater body fat values than female runners, jumpers, divers and gymnasts. Of particular interest is the suggestion that while average values for body composition are clearly

different among sports, for athletes within a particular sport there is rarely a high correlation between competition and performance. Therefore, it is possible that skinfold comparisons of individual basketballers as a method of team selection or talent identification could be considered inaccurate, unjust and unfair. There is substantial need for further investigation into the skinfold and percent body fat values of women basketballers. In particular, research should consider whether changes in body composition will impact on basketball performance, and whether establishing an 'ideal' sum of skinfolds or percent body fat range for elite women basketballers is an appropriate or desirable task.

5.2.2 Maximal Aerobic Power (VO_2 max) Profile

The maximal effort data of the guards and the forwards/centres again demonstrated the homogeneity of the participating groups. The similarities in training demands may subsequently be associated with the observed closeness in VO_2 max scores. Very few studies have examined positional differences in VO_2 max for elite women's basketball. However, comparisons with studies of similar populations revealed a consistency in the overall group VO_2 max results with only minimal differences being observed.

5.2.3 Submaximal Markers of Exercise Metabolism

More sensitive measures of change in fitness may, however, be more readily located within submaximal metabolic intensity. Differences were found in the lactate threshold and ventilatory break point of guards and forwards/centres. No difference in the peak blood lactate concentrations was evident between the two groups following maximal effort. These data suggested that positional differences occurred submaximally with an advantage in prolonged aerobic metabolism in favour of the guards. Possible explanations for this may lie in the muscle fibre distribution and running economy of the two groups. It is also possible that differences in exercise

performance due to 'on-court' experiences may have contributed to the results in the present study.

5.2.4 Relative Intensity During Competitive Games

The intermittent nature of the sport perhaps masks the dominance of the aerobic energy contribution to the sport. High intensity interval training has been reported to impose intensive stimuli to both anaerobic and aerobic energy supplies. The reliance of the game on extended speed and agility movements tends to infer that high intensity interval training should subsume a high proportion of the endurance training program.

Despite a limited number of studies investigating the absolute and relative heart rate intensities of competitive basketball performance, the mean values found in the present study were comparable with studies involving other intermittent sports. The most significant finding was no difference in the absolute and relative heart rate values of the guards and the forward/centres. This may be explained by mean values being insensitive to individual differences in submaximal intensity.

The intense nature of elite women's basketball was further demonstrated in the finding that the majority of live time was spent above 85% HR max and approximately one quarter of live time was spent at a heart rate above 95% HR max. It would appear that competitive basketball performance elicits a greater proportion of time between 85 and 95% HR max than other intermittent team sports. This may be explained by differences in court sizes, governing rules, movement patterns and positional responsibilities. Using heart rate training zones and the findings of the present study, it would appear training sessions specific to women's basketball should involve players experiencing a high proportion of high intensity interval training.
The blood lactate concentrations recorded during competition imply that glycolysis is an important energy source during competitive basketball

performance. A major finding was that the highest blood lactate concentration was recorded ten minutes into the first half. The motivation levels of players following an extensive preparation leading into the match may explain this. Low blood lactate concentrations in the second half, particularly at the end of the game, were comparable with previous soccer and hockey research. It is possible that lower work to rest ratios caused by predictable game results and/or lower muscle glycogen concentrations may explain this phenomenon. It may also be possible that as the game progressed the players either produced less or became more efficient at clearing accumulated lactate while still participating at relatively high intensities.

5.2.5 Estimates of Sweat Loss During Competition

Sweat loss, estimated from changes in pre and post game body mass, indicated that players did not consume enough fluid to maintain their pre-game weight. Body fluid loss may contribute negatively to performance toward the end of a match. Increased fluid intake during competitive performance can be useful in supplying the body with carbohydrates as well as reducing a net loss of body water. Further studies examining the optimum concentration of carbohydrate, electrolyte content, volume, temperature and frequency of ingestion for elite women's basketball performance should be conducted.

5.3 CONCLUSIONS AND RECOMMENDATIONS

1. **The physiological mechanisms contributing to elite women's basketball performance have not been well documented in the literature.**

Despite a plethora of research profiling descriptive data of elite women basketballers (height, body mass, age, skinfolds and VO_2 max) little, if any, exists detailing heart rates, sweat loss, blood lactate concentration and other physiological responses during competitive performance. This type of information would seem useful for coaches and sports scientists to know. In particular, it could be used to establish training targets and prescribe exercise programs to enhance the physiological performance of this population and elite female sportspeople in general.

Therefore, it is recommended that investigation into the physiological responses of elite women basketballers during competitive performance continue. Furthermore, results of the present study would be complimented by more broadly based longitudinal studies, such as research conducted over the course of a number of seasons.

2. **Limited physiological differences exist between positional groups of elite women basketballers.**

The present study found very few differences in the physiological responses of elite women basketballers according to position. Apart from the obvious differences in body mass and height, no difference was found in the sum of skinfolds, body mass index and maximal effort data of the guards and forwards/centres measured in the laboratory. In addition, similarities were found in field-based measures, such as mean absolute and relative heart rates and blood lactate concentrations during competitive matches. This indicates that elite players, regardless of position, spend a large proportion of playing

time at high intensities and experience similar energy contribution responses at various stages in the game. These findings were likely to reflect changes in the style of the elite women's game of basketball and the training protocols over recent years.

The introduction of structured coaching programs throughout Australia has been reported to have a positive impact on the game of basketball. Today's women players are described as possessing a greater level of skill, more versatile and better prepared physically and mentally than players of past generations. Consequently, coaches of the modern game expect players to fulfil a greater number of roles. With offensive and defensive play now structured to reflect the versatility of players - guards, forwards and centres find themselves in a variety of positions at different times of the game. It is likely that similarities in the conditioning training prescribed for the present sample of athletes contributed to the closeness in laboratory testing results. The finding of no difference in the mean game intensities of guards and forwards/centres could reflect similarities in the 'on-court' experiences of players in these positions. Despite the possibility of subtle variations in movement patterns, large differences were not expected due to the likelihood of mean values being insensitive to differences in intensity. Furthermore, similar increases in blood lactate concentration compared to pre-game values suggest that glycolysis is an important energy source during competitive basketball performance, regardless of position.

It is recommended that the similarities in the responses of guards and forwards/centres, both in the laboratory and on the court, be promoted widely. This will help to ensure that the quality of coaching in the sport reflects the quality of the sporting experience for women players, regardless of position.

In addition to the similarities in the physiological responses of players, the present study also found that while glycolysis makes a significant

contribution to the energy pool during a game, women players may not tax the anaerobic energy systems as highly as male players. However, the limited number of investigations into blood lactate concentrations during both female and male basketball competitions does not allow accurate conclusions to be drawn. Hence, it is recommended that further investigation in this area be conducted.

3. **The physiological responses of elite women basketballers have implications for exercise prescription and for education programs for coaches, players and officials.**

It has been suggested that while body composition variations exist between different sports, the correlation between body composition and performance within a sport is rarely high. This would suggest that skinfold comparisons of individual basketballers are inaccurate, unjust and unfair for talent identification and team selection. It would appear there is a substantial need for further investigation into the skinfold and percent body fat values of elite women basketballers. Therefore, it is recommended that research be conducted to investigate whether changes in body composition impact on performance and whether the establishment of a percent body fat range or 'ideal' sum of skinfolds for elite women basketballers is an appropriate or desirable task.

Lactate threshold and ventilatory break point data indicated submaximal differences in terms of position, with an advantage in prolonged aerobic metabolism in favour of the guards. Given these differences, absolute intensities are likely to be higher in the guards. This is important in describing their actual role in the game. Research into the distances covered by different positional players would assist in investigating whether in fact guards cover more of the court than forwards and centres during a game. In addition, research into the muscle fibre distribution and running economy of

positional groups may establish whether these two possible causes contribute to this finding.

It is generally believed that high intensity intervals are more effective in improving aerobic power and perhaps the lactate threshold than low intensity training. Live time heart rates and blood lactate concentrations recorded during competitive women's play suggest that high intensity training appears to be the most appropriate training technique for the sport of basketball. High intensity exercise is linked to significant glycolytic activity. Therefore, coaches should be educated in ways of improving the capacity of this energy pathway. In general, high intensity intervals of 20 to 60 seconds duration should be included in the athletes training schedule to overload this metabolic pathway. This form of training would perhaps be best introduced during the *specific training phase* of a periodised schedule. However, given that this type of exercise may significantly reduce glycogen stores, it is recommended that hard interval days be followed with lighter training sessions. Continuous training at and above the lactate threshold may be relevant when prescribing exercise for players who have incurred lengthy periods away from the game, or who have less than desirable pre-training fitness levels. This type of training would be best introduced in the *general preparation phase* of the conditioning program.

Overall sweat loss and body mass changes in this study give rise to the need for education on the importance of players establishing hydration practices during training and competition. This is further supported by the fact that there are sufficient opportunities throughout the game of basketball for players to maintain hydration in normal environmental conditions (20°C $\pm$ 2°C). In particular, the present study supports the recommendation that players should consume 600 to 1000 $ml.hr^{-1}$ during competitive performance. Coaches should support fluid intake by encouraging all players to have a drink bottle at each session and by scheduling regular drink breaks. Players should be encouraged to monitor their fluid needs by weighing themselves

before and after both competition and training in different environmental conditions. There is an additional possibility that carbohydrate supplementation may be beneficial to intermittent performance. Therefore, it is recommended that further studies be conducted which examine the optimum concentration of carbohydrate, electrolyte content, volume, temperature and frequency of ingestion for elite women's basketball.

In summary, this study has described relatively high physiological demands in competitive practices of a group of elite women basketballers. Importantly, it has challenged the sensitivity of traditionally laboratory based testing and has gained more insight from submaximal, rather than maximal performance based tests. It has further challenged the appropriateness of anthropometric standards being applied to a population of relatively tall and heavy women athletes. Limited studies available made comparison with the present study difficult. The research has recommended salient directions for future exercise prescription practices, and applied research in women's basketball.

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APPENDIX [1]

Descriptive Data of Women's National Basketball League Players

Position	**Age**	**Mass**	**Height**	**Body Mass Index (BMI)**
Forward/Centre	31	78.5	182.5	23.6
Guard	27	67.6	176.5	21.7
Forward/Centre	27	88.0	183.5	26.1
Guard	24	63.8	170.1	22.1
Guard	20	62.0	162.0	23.9
Forward/Centre	26	85.4	182.5	25.6
Forward/Centre	27	73.3	180.5	22.6
Guard	20	66.1	165.3	24.2
Forward/Centre	18	71.3	182.7	21.4
Forward/Centre	20	105.0	194.1	27.9
Guard	24	73.2	172.3	24.7
Guard	24	75.0	175.6	24.4
Forward/Centre	25	69.2	182.3	20.8
Guard	19	62.9	171.4	21.5
Mean ± SD	23 ± 4	74.4 ± 11.9	177.2 ± 8.5	23.6 ± 2.1

APPENDIX [2]

Analysis of Descriptive Data of Women's National Basketball League Players by Position

Dependent Variable	**df**	**F Ratio**	**F Probability**
Age (yrs)	1, 12	1.28	0.28
Body Mass (kg)	1, 12	7.74	0.02*
Height (cm)	1, 12	26.70	0.0002*
Body Mass Index ($kg.m^2$)	1, 12	0.53	0.48

p* = probability level between mean $p<0.05$

APPENDIX [3]

Maximl Effort (VO_2 max) Characteristics of Women's National League Players

Position	**VO_2 max ($l.min^{-1}$)**	**VO_2 max ($ml.kg^{-1}.min^{-1}$)**	**RER max**	**Max HR ($b.min^{-1}$)**
Forward/Centre	3.47	43.85	1.16	189
Guard	3.77	56.05	1.22	203
Forward/Centre	4.92	56.61	1.05	196
Guard	3.01	47.22	1.20	184
Guard	3.28	53.06	1.30	203
Forward/Centre	3.83	45.13	1.30	194
Forward/Centre	3.43	46.75	1.17	184
Guard	3.18	45.99	1.15	203
Forward/Centre	3.22	45.15	1.28	203
Forward/Centre	5.03	47.94	1.15	206
Guard	3.87	52.93	1.24	189
Guard	3.22	44.84	1.20	173
Forward/Centre	3.59	52.70	1.17	188
Guard	2.90	46.14	1.19	193
Mean ± SEM	3.62 ± 0.17	48.88 ± 1.18	1.20 ± 0.02	193 ± 3

RER = Respiratory Exchange Ratio

APPENDIX [4]

Analysis of Maximal Effort (VO_2 max) Characteristics of Women's National Basketball League Players by Position

Dependent Variable	**df**	**F Ratio**	**F Probability**
Max HR ($b.min^{-1}$)	1, 12	0.10	0.75
VO_2 max ($l.min^{-1}$)	1, 12	3.80	0.07
VO_2 max ($ml.kg^{-1}.min^{-1}$)	1, 12	0.23	0.64
RER max	1, 12	0.74	0.41

p* = probability level between mean $p<0.05$

APPENDIX [5]

Skinfold Measurements of Women's National League Players

Subject Position	Bicep (mm)	Tricep (mm)	Subscapula (mm)	Suprailiac (mm)	Mid-abdomen (mm)	Total (mm)
Guard	7.1	19.0	9.7	9.5	16.5	61.8
Forward/ Centre	8.2	21.1	9.3	7.1	13.5	59.2
Forward/ Centre	5.3	10.6	7.7	5.9	16.2	45.7
Forward/ Centre	6.4	4.8	16.8	14.8	21.3	64.1
Forward/ Centre	9.6	21.0	11.6	16.2	25.1	83.5
Guard	6.0	22.2	8.9	7.5	11.5	56.1
Guard	7.2	15.3	10.7	9.8	19.1	62.1
Forward/ Centre	8.6	19.4	10.6	16.6	26.0	81.2
Forward/ Centre	6.5	14.1	8.0	7.3	14.6	50.5
Guard	7.8	16.9	13.0	8.6	10.4	56.7
Forward/ Centre	17.1	26.1	16.2	20.2	28.9	90.9
Guard	7.2	25.0	13.1	9.4	21.2	75.9
Guard	8.3	11.3	9.4	13.4	21.2	63.6
Guard	7.2	12.9	8.1	5.7	8.1	42.0
Guard	9.1	17.4	12.2	9.5	16.8	65.0
Guard	8.2	21.1	9.3	7.1	13.5	59.2
Guard	5.3	10.2	6.6	6.7	9.6	38.4
Forward/ Centre	9.2	16.2	12.2	10.4	22.2	70.2
Forward/ Centre	6.6	14.4	9.1	10.6	15.7	56.4
Mean ± SEM	7.9 ± 0.6	16.8 ± 1.3	10.7 ± 0.6	10.3 ± 0.9	17.4 ± 1.3	62.2 ± 3.2

APPENDIX [6]

Analysis of Skinfold Measurements of Women's National Basketball League Players According to Position

Dependent Variable	df	F Ratio	F Probability
Bicep	1, 17	1.19	0.30
Tricep	1, 17	0.08	0.74
Subscapula	1, 17	0.86	0.37
Mid-Abdomen	1, 17	5.47	0.03*
Suprailiac	1, 17	3.83	0.07
Total	1, 17	2.04	0.17

p* = probability level between mean $p<0.05$

APPENDIX [7]

Lactate Profile Data of Women's National League Basketball Players

Position	**Pre-test mM**	**8 kph mM**	**10 kph mM**	**12 kph mM**	**13 kph mM**	**14 kph mM**	**Max mM**
Forward/ Centre	3.4	2.1	1.8	2.3	2.4	4.5	10.1
Forward/ Centre	3.0	3.8	4.0	4.7	7.7	-	9.1
Forward/ Centre	4.2	3.4	5.2	4.7	6.6	8.3	9.8
Forward/ Centre	3.7	1.7	1.6	3.5	3.7	-	10.2
Forward/ Centre	2.2	3.5	3.7	3.1	6.6	-	8.3
Forward/ Centre	3.7	4.4	4.7	3.5	5.1	-	6.6
Forward/ Centre	3.9	4.7	4.9	8.6	10.2	-	12.1
Forward/ Centre	1.6	3.3	3.9	6.1	6.1	-	11.5
Guard	2.9	2.1	2.4	2.1	2.7	3.5	6.9
Guard	3.7	2.8	2.4	3.6	3.0	3.9	9.1
Guard	2.5	2.0	2.4	2.7	3.3	4.6	9.2
Guard	3.3	3.8	3.9	3.1	6.7	-	7.8
Guard	3.1	3.8	1.7	2.1	2.5	-	9.7
Guard	1.6	1.6	2.4	2.7	2.8	-	7.9
Guard	1.2	1.6	2.4	3.7	3.9	6.4	8.8
Guard	1.6	2.0	1.6	2.1	3.0	-	6.2
Mean ± SEM	2.9 ± 0.2	2.9 ± 0.3	3.1 ± 0.3	3.7 ± 0.4	4.8 ± 0.5	5.2 ± 0.7	9.0 ± 0.4

APPENDIX [8]

Analysis of Total Group Lactate Profile Data

			Grp 1	Grp 2	Grp 3	Grp 4	Grp 5	Grp 6	Grp 7
	Mean	Time							
Pre	2.8769	Grp 1							
8 kph	2.9125	Grp 2							
10 kph	3.0625	Grp 3							
12 kph	3.6625	Grp 4							
13 kph	4.7688	Grp 5	*	*	*				
14 kph	5.2000	Grp 6							
Max	8.5813	Grp 7	*	*	*	*	*	*	*

* Indicates significant differences

APPENDIX [9]

Analysis of Lactate Profile Data of Guards

			Grp 3	Grp 2	Grp 1	Grp 4	Grp 5	Grp 6	Grp 7
	Mean	Time							
10 kph	2.40	Grp 3							
8 kph	2.46	Grp 2							
Pre	2.49	Grp 1							
12 kph	2.76	Grp 4							
13 kph	3.49	Grp 5							
14 kph	4.60	Grp 6	*	*	*	*			
Max	8.20	Grp 7	*	*	*	*	*	*	*

* Indicates significant differences

APPENDIX [10]

Analysis of Lactate Profile Data of Forwards/Centres

			Grp 1	Grp 2	Grp 3	Grp 4	Grp 5	Grp 6	Grp 7
	Mean	Time							
Pre	3.21	Grp 1							
8 kph	3.36	Grp 2							
10 kph	3.73	Grp 3							
12 kph	4.56	Grp 4							
13 kph	6.05	Grp 5							
14 kph	6.40	Grp 6							
Max	9.71	Grp 7	*	*	*	*	*		

* Indicates significant differences

APPENDIX [11]

Analysis of Lactate Profile Data of Women's National Basketball League Players According to Position

Dependent Variable	**df**	**F Ratio**	**F Probability**
La Rest	1, 14	2.55	0.13
La 8 kph	1, 14	3.44	0.08
La 10 kph	1, 14	6.06	0.03*
La 12 kph	1, 14	5.65	0.03*
La 13 kph	1, 14	6.89	0.02*
La 14 kph	1, 14	1.42	0.30
La max	1, 14	4.04	0.06

p* = probability level between mean $p<0.05$

APPENDIX [12]

Ventilatory Threshold Data of Elite Women Basketballers

Subject Position	**Ventilatoy Break-Point: Time (min)**	**Ventilatory Breakpoint Heart Rate (VBP HR) ($b.min^{-1}$)**	**Maximum Heart Rate ($b.min^{-1}$)**	**VBP HR as a % of Maximum Heart Rate**
Guard	8:30	180	188	96
Guard	7:00	180	184	98
Guard	6:45	180	189	95
Guard	7:30	190	203	94
Guard	7:30	195	203	96
Guard	6:45	175	184	95
Guard	7:00	185	193	96
Guard	7:00	190	203	94
Forward/Centre	7:00	185	194	95
Forward/Centre	5:45	190	203	94
Forward/Centre	5:45	180	192	94
Forward/Centre	7:00	185	193	96
Forward/Centre	6:45	180	194	93
Forward/Centre	6:45	190	196	97
Forward/Centre	6:30	165	180	92
Forward/Centre	5:15	190	206	92
Forward/Centre	7:00	180	188	96
Mean ± SEM	6.81 ± 0.15	184 ± 2	194 ± 2	95 ± 0

VBP = Ventilatory Break Point

APPENDIX [13]

Absolute and Relative Heart Rate Intensities of Elite Women Basketballers During Competitive Performance

Position	**Maximum Heart Rate ($b.min^{-1}$)**	**Mean Heart Rate Live Time ($b.min^{-1}$)**	**%Max**	**Mean Heart Rate Total Game Time ($b.min^{-1}$)**	**%Max**
Forward/Centre	189	171	90	133	70
Guard	203	190	94	169	83
Forward/Centre	196	185	94	146	75
Guard	184	168	91	151	82
Guard	203	184	91	174	86
Forward/Cen	194	177	91	149	77
Forward/Cen	184	166	90	155	84
Guard	203	183	90	176	87
Forward/Cen	203	185	91	169	83
Forward/Cen	206	188	91	157	76
Guard	189	172	91	160	85
Guard	173	156	90	122	71
Mean ± SEM	194 ± 3	177 ± 0	91 ± 0	155 ± 5	80 ± 2

APPENDIX [14]

Analysis of Absolute and Relative Heart Rate Intensities of Elite Women Basketballers During Competitive Basketball Performance According to Position

Dependent Variable	**df**	**F Ratio**	**F Probability**
Mean heart rate maximum	1, 10	0.21	0.66
Mean live time heart rate	1, 10	0.23	0.64
Mean total game heart rate	1, 10	0.57	0.47
Live time heart rate as a percentage of heart rate maximum	1, 10	0.05	0.83
Total game heart rate as a percentage of heart rate maximum	1, 10	2.05	0.18

p* = probability level between mean $P<0.05$

APPENDIX [15]

Blood Lactate Concentrations of Elite Women Forward/Centre Players During Competitive Performance

	Subject								
Time	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Mean ± SEM**
Pre-game lactate	1.6	3.2	1.9	1.8	2.8	3.4	2.8	4.4	2.7 ± 0.3
10 minute lactate (1st half)	7.3	8.5	3.5	8.8	5.3	8.6	7.3	10.5	7.5 ± 0.8
Half-time lactate	4.7	6.8	3.0	3.5	4.5	6.5	4.7	5.5	4.9 ± 0.5
10 minute lactate (2nd half)	5.9	5.3	2.8	4.4	3.6	3.7	5.7	9.1	5.1 ± 0.7
Full-time lactate	4.1	4.6	1.5	3.3	3.4	4.3	3.6	-	3.5 ± 0.4

APPENDIX [16]

Blood Lactate Concentrations of Elite Women Guard Players During Competitive Performance

	Subject							
Time	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Mean ± SEM**
Pre-game lactate	4.6	1.9	1.8	2.7	2.3	2.2	3.4	2.7 ± 0.4
10 minute lactate (1st half)	11.6	4.1	5.8	9.0	5.7	10.1	5.1	7.3 ± 1.1
Half-time lactate	8.0	3.6	4.4	5.4	9.0	-	3.7	5.7 ± 0.9
10 minute lactate (2nd half)	16.3	2.7	1.2	5.7	5.0	6.0	6.6	6.2 ± 1.8
Full-time lactate	9.5	3.2	2.5	7.6	5.9	4.6	3.0	5.2 ± 1.0

APPENDIX [17]

Analysis of Blood Lactate Concentrations Recorded During Competitive Performance According to Position

Dependent Variable	**df**	**F Ratio**	**F Probability**
Pre	1, 13	0.01	0.94
10 minutes (1st Half)	1, 13	0.13	0.90
Half Time	1, 13	0.65	0.44
10 minutes (2nd Half)	1, 13	0.38	0.55
Full Time	1, 13	2.49	0.14

p* = probability level between mean P<0.05

APPENDIX [18]

Analysis of Total Group Blood Lactate Concentrations Recorded During Competitive Performance

			Grp 1	Grp 5	Grp 3	Grp 4	Grp 2
	Mean	Time					
Pre	2.7200	Grp 1			*	*	*
Full Time	4.3500	Grp 5					
Half Time	5.2400	Grp 3					
10 min (1st)	5.6000	Grp 4					
10 min (2nd)	7.4100	Grp 2	*	*	*	*	

* Indicates significant differences

APPENDIX [19]

Total Body Mass Loss of Elite Women Basketballers Measured During Competitive Performance

Subject	Body Weight Loss (kg)	Fluid Intake (litres)	Net Body Mass Loss/ Estimated Sweat Loss (litres)
1	0.7	0.5	1.2
2	-0.2	1.0	0.8
3	0.4	1.1	1.5
4	0.2	1.0	1.2
5	-0.2	1.0	0.9
6	0.2	0.5	0.7
7	0.8	0.3	1.1
8	0.4	0.8	1.2
9	0.0	0.8	0.8
10	0.4	1.1	1.5
11	-0.2	1.5	1.3
12	0.4	0.8	1.2
13	0.0	0.8	0.8
14	-0.8	1.5	0.7
15	0.4	1.2	1.6
16	0.2	1.7	1.9
Mean ± SEM	0.2 ± 0.1	1.0 ± 0.1	1.1 ± 0.1

APPENDIX [20]

Relative Perceived Exertion Scores of Elite Women Basketballer Recorded During Competitive Performance

Subject	10 minutes (1st half)	Half Time	10 minutes (2nd half)	Full Time
1	18	13	12	15
2	17	14	16	15
3	19	18	17	16
4	17	17	-	17
5	-	17	14	16
6	13	15	15	17
7	15	17	18	17
8	17	15	16	15
9	13	13	14	
10	15	15	12	18
11	11	12	12	-
12	-	13	7	12
13	16	15	12	11
Mean ± SEM	16 ± 1	15 ± 1	14 ± 1	15 ± 1

APPENDIX [21]

Descriptive Data of Under 18 Elite Female Basketballers

Subject	**Age (yrs)**	**Height (cm)**	**Armspan (cm)**	**Weight (kg)**	**BMI ($kg.m^2$)**
1	16	180.7	179.0	61.7	18.9
2	16	180.5	185.7	68.4	21.0
3	16	166.5	161.4	-	-
4	16	168.2	162.0	50.8	18.0
5	16	174.2	174.0	69.0	22.7
6	17	163.1	163.2	65.8	24.7
7	16	179.6	178.5	69.6	21.6
8	16	172.3	165.0	62.0	20.9
9	17	175.5	170.2	62.8	20.4
10	16	178.0	174.3	68.2	21.5
11	17	175.8	175.8	75.0	24.3
12	17	165.0	163.3	61.2	22.5
13	16	190.0	193.9	82.4	22.8
14	17	177.5	177.4	75.5	24.0
15	16	168.8	169.0	58.0	20.4
16	16	162.7	167.9	63.2	23.9
17	17	178.6	185.3	81.3	25.5
18	17	180.8	187.1	76.0	23.3
Mean $\pm$ SEM	16 $\pm$ 0	174.3 $\pm$ 1.7	173.1 $\pm$ 2.2	67.7 $\pm$ 2.0	22.1 $\pm$ 0.5

BMI = Body Mass Index

APPENDIX [22]

Fitness Profile of Elite Under 16 Female Basketballers

Subject	**20m Sprint (0-10m) (sec)**	**20m Sprint (0-20m) (sec)**	**Sit Ups (60 sec)**	**Agility Test (sec)**	**Suicide Test (sec)**	**Sit & Reach (cm)**	**20m Multi-stage Shuttle Run Test (stage)**
1	1.9	3.4	35	5.6	30.5	7	9.1
2	2.0	3.4	40	5.9	30.9	8	8.5
3	1.9	3.4	37	5.8	30.6	12	9.9
4	2.2	3.8	26	6.7	33.0	19	5.6
5	1.9	3.6	30	6.0	32.9	17	6.9
6	2.0	3.6	35	6.5	32.6	19	5.1
7	2.0	3.5	46	5.7	32.0	14	7.5
8	1.9	3.3	45	5.9	30.8	14	8.5
9	1.8	3.2	49	5.6	29.2	15	7.9
10	2.0	3.5	46	6.2	31.5	9	8.3
11	2.0	3.7	42	6.4	32.4	4	9.3
12	2.0	3.4	50	5.7	31.3	15	8.1
13	1.9	3.4	38	6.0	30.9	3	8.4
14	1.9	3.4	39	6.0	31.4	6	8.4
Mean ± SEM	2.0 ± 0.0	3.5 ± 0.0	40 ± 2	6.0 ± 0.1	31.4 ± 0.3	12 ± 1	8.0 ± 0.4

APPENDIX [23]

Fitness Profile of Elite Under 18 Female Basketballers

Subject	20m Sprint (0-10m) (sec)	20m Sprint (0-20m) (sec)	Sit Ups (60 sec)	Agility Test (sec)	Suicide Test (sec)	Sit & Reach Test (cm)	20m Multi-Stage Shuttle Run Test (stage)
1	1.9	3.4	56	5.9	-	-2	-
2	2.0	3.5	54	6.3	31.2	19	8.2
3	1.9	3.4	46	6.4	-	16	-
4	1.8	3.2	52	5.3	28.8	18	11.5
5	1.9	3.4	43	5.6	29.1	16	9.8
6	1.9	3.3	51	5.4	29.9	17	9.8
7	1.8	3.2	54	5.7	30.8	13	7.9
8	1.9	3.4	39	5.8	29.6	-2	9.1
9	-	3.4	41	5.9	30.7	16	9.5
10	-	3.3	45	5.7	30.9	18	8.3
11	-	3.3	42	5.2	30.6	20	9.2
12	-	3.4	50	5.7	32.1	17	10.5
13	-	3.6	42	6.4	33.0	12	7.5
14	-	3.4	56	5.9	30.9	16	10.3
15	-	3.3	58	5.4	28.9	0	10.6
16	-	3.1	58	5.0	30.0	-	10.5
17	-	3.3	54	5.3	27.6	21	9.5
18	-	3.3	46	5.6	30.8	20	8.3
Mean ± SEM	1.9 ± 0.0	3.3 ± 0.0	49 ± 1	5.7 ± 0.1	30.3 ± 0.3	14 ± 2.0	9.4 ± 0.3

APPENDIX [24]

Descriptive Data of Under 16 Elite Female Basketballers

Subject	**Age (yrs)**	**Height (cm)**	**Armspan (cm)**	**Weight (kg)**	**BMI ($kg.m^2$)**
1	14	168.5	171.4	56.8	20.0
2	15	173.4	184.5	69.5	23.1
3	14	168.9	165.0	56.4	19.8
4	15	183.5	190.0	86.4	25.7
5	14	178.4	184.4	71.8	22.6
6	15	171.8	177.9	82.0	27.8
7	14	168.3	169.5	63.4	22.4
8	13	178.5	187.0	63.8	20.0
9	14	176.0	172.5	63.0	20.3
10	14	185.0	179.0	73.0	21.3
11	14	187.8	184.7	79.6	22.6
12	14	173.6	171.1	61.6	20.4
13	14	181.5	174.7	69.0	21.0
14	14	167.5	168.0	68.2	24.3
Mean ± SEM	14 (± 0)	175.9 ± 1.8	177.1 ± 2.1	68.9 ± 2.4	22.2 ± 0.6

BMI = Body Mass Index

APPENDIX [25]

Lactate Threshold Data of Elite Women Basketballers (Guards)

Subject	**Lactate Threshold Speed ($km.hr^{-1}$)**
1	12
2	12
3	12
4	12
5	12
6	13
7	10
8	12
Mean ± SEM	12 ± 0

APPENDIX [26]

Lactate Threshold Data of Elite Women Basketballers (Forwards / Centres)

Subject	**Lactate Threshold Speed ($km.hr^{-1}$)**
1	10
2	10
3	8
4	10
5	10
6	12
7	12
8	10
Mean $\pm$ SEM	10 ± 0