Quantification of physical load in elite junior Australian football players

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Submitted in fulfilment of the requirements for the degree of Master of Applied Science (Research)

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Declaration

DEAKIN UNIVERSITY
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Abstract

This thesis quantified the physical load within the elite junior Australian football (AF) player. The primary aim was to investigate the typical in-season physical load exposure of the elite junior AF player in game and training sessions, and other modes of physical activity using objective device technologies and subjective data captured within training diaries. The secondary aim was to assess the relationships between the subjective session RPE method and objective GPS time motion analysis (TMA) and heart rate (HR) data in sessional training load of elite junior AF players. The study collected data over a 19 week period from 63 participants during the 2009 under 18 Transport Accident Commission Cup (TAC Cup) competition.

The first part of this thesis investigated the typical weekly physical load exposure of metropolitan and rural elite junior AF player’s using individual training diaries. Players who were selected to play a game of TAC Cup football undertook a significantly higher (p<.001) amount of total mean weekly physical load (434 min) than those who did not play TAC Cup football (388 min). Total weekly physical load was also significantly greater (p<.001) for players from metropolitan teams (428 min) compared to players from a rural club (400 min). An overwhelming majority (95%) of players’ physical load was in the mode of weight-bearing activities.

In part two, investigation into the physical demands of elite junior AF during game and training sessions using GPS TMA and HR monitoring demonstrated differences in both the external and internal physical load variables. Game sessions lasted longer in duration compared to training sessions, with mean ± SD values of 103 ± 13 and 87 ± 25 min respectively. Additionally, elite junior AF players were exposed to a higher physical load output from a game session in comparison to a training session, with the majority of the reported variables being higher in games including total distance and average HR.

For part three, the relationship between physical load GPS TMA and HR variables and self-reported session RPE from training sessions were explored using multiple regression analysis. The model using the predictor factors of high intensity running and time spent between 50-80% of predicted HRmax explained 21.3% of the variance in session RPE.

Results from this thesis provide insights into the physical loads experienced by the elite junior Australian footballer. The information presented can assist in the
facilitation of best practice advice for player management and training prescription through the use of training diaries and GPS TMA and HR device technologies.
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Abbreviations

AF: Australian football
AFL: Australian Football League
ANOVA: One way analysis of variance
AU: Arbitrary units
BPM: Beats per minute
CR1-10: Ratio 1-10 scale
CV: Coefficient of variation
GPS: Global positioning system
HR: Heart rate
HRM: Heart rate monitoring
HR_{peak}: Heart rate peak
HR_{max}: Heart rate maximum
HR_{reserve}: Heart rate reserve
OF: Other football
RPE: Rating of perceived exertion
REST-Q Sport: Recovery-Stress Questionnaire for athletes
SD: Standard Deviation
TAC Cup: Transport Accident Commission Cup
TL: Training load
TMA: Time motion analysis
TRIMP: Training impulse
VO_{2max}: Maximal oxygen uptake
% HR_{max}: Percentage of heart rate maximum
Chapter one: Introduction

1.1 Introduction

Typically, athletic performances incorporate the basic physiological components of strength, speed and endurance combined with skill and psychological factors (Desgorces, Senegas et al. 2007). Optimising training involves quantifying an athlete’s current training status and whether they are adapting favourably to the training prescribed (Borresen and Lambert 2009). Traditionally, the prescription of exercise training has largely been instinctive, with the variables of intensity, volume, frequency and time of training being increased in a random manner, in the belief that an increase in training will develop performance improvement in an athlete (Borresen and Lambert 2008b). This approach to training prescription is not conducive to optimal physiological adaptation, and raises the potential for injury and overtraining (Williams and Eston 1989).

There are two types of physical load: internal and external. External training load is prescribed by the coach or fitness staff depending on the aims and intended outcomes of the session. Internal training load is derived from the physiological strain that an athlete is subjected to within a training session (Impellizzeri, Rampinini et al. 2005). Effective coaching requires an ability to control, manipulate and monitor internal training load (Impellizzeri, Rampinini et al. 2004). Understanding the mechanisms of internal training load is particularly important in team sport environments, where the external load within training is often the same for each member of the team due to the prescription and dominant use of group exercise and training (Impellizzeri, Rampinini, et al. 2005).

Optimal performance strategies centre on the design and implementation of a training program within an annual plan that maximises performance and minimises the risk of fatigue and overtraining (Smith 2003). Various methods have been used to quantify training load, including measures of heart rate, blood lactate, rating of perceived exertion, and the use of mathematical modelling and training indices. A current limitation within the literature is that there is no universal method to quantify training load within individual or team sports, or across varying modes of exercise.

Despite the increased professionalism of adolescent sport and improved development pathway programs to elite adult participation, data on the elite junior
Australian football (AF) player is under-explored (Burgess, Naughton et al. 2012). Currently there is no universally accepted method of monitoring physical load, or a single identifiable physiological marker that can measure the fitness and fatigue response of an athlete (Borresen and Lambert 2009). Understanding and quantifying physical load is important for establishing targeted and effective training and recovery guidelines for coaching staff and players. To date, no study has formally measured the physical activity and training loads of the elite junior AF player, with only limited data available on game demands (Veale, Pearce et al. 2007; Veale and Pearce 2009a; Veale and Pearce 2009b; Burgess, Naughton et al. 2012). Advancements in Global Positioning System (GPS) units now make investigations into the external game and training loads in field team sports such as AF possible.

Given the limited data on physical training loads in junior AF, the purpose of this thesis was to investigate the typical weekly physical load exposure of elite junior AF players within game and training environments, with particular reference to the use of training diaries, GPS Time Motion Analysis (TMA) and Heart Rate Monitoring (HRM) technology. In accordance with previous research, time motion analysis (Coutts, Quinn et al. 2010b), heart rate measures (Foster, Florhaug et al. 2001) and the recording of an individual’s sessional Rating of Perceived Exertion (Foster, Florhaug et al. 2001) within a training diary were used to quantify physical load of elite junior AF players. Specifically, this thesis examined the game and training load of elite junior AF players within the Transport Accident Commission Cup (TAC Cup) competition. Players within the TAC Cup competition were chosen as they are elite junior athletes with a high exposure to training loads in football and other sports (Finch, Donohue et al. 2002).
1.2 Research aims

The overall aim of this thesis was to establish the typical physical load exposure of the elite junior AF player within game and training sessions, using GPS TMA, HRM, and player training diary data collection methods. Player training diaries measured typical weekly physical activity profiles of the elite junior AF player. Individually worn GPS and HRM provided detailed measures of external and internal load in competition and training environments. In addition, an evaluation of the relationships between objective GPS TMA and HR data assessed the appropriateness of using a subjective feedback mechanism, the session RPE method, to quantify sessional physical load within elite junior AF.

Three specific aims investigated were:

1. To describe the typical weekly physical load profiles of elite junior AF players using training diaries.
2. To describe the physical demands of elite junior AF during training and competition using GPS TMA and HRM.
3. To examine the relationships between objective (GPS TMA and HR) and subjective feedback (session RPE) measures of training sessions in elite junior AF players.

1.3 Significance

This research will add to current sports science and human performance knowledge by improving the understanding of the physical activity profiles, including the typical external and internal game and training loads within elite junior AF. In addition, comparison of the session RPE method with established objective load and intensity measures will assess the validity of its application within junior elite AF as a measure of assessing global training load. As GPS technology is not readily accessible or financially viable within junior AF clubs, serial monitoring of session RPE with a training diary is an alternative means of monitoring physical load. This can further assist in the periodisation of individual and team training and recovery programs. Finally, information gained from this project may be transferable to other sports that have similar development programs in place.
Chapter two: Review of literature

The review of literature examines the critical factors that affect the physical game and training demands evident within elite junior AF. The areas of youth athletes, Australian football (including game demands), physical load and overtraining are discussed within this chapter. Additionally, insights into the methods and technologies employed to monitor physical load reported within the literature are described. These include both objective and subjective applications of monitoring physical load, including HRM, the training impulse method, session rating of perceived exertion and the use of GPS monitoring, including their reliability and validity as a means to monitor aspects of physical load.

2.1 Youth athletes

A change in the balance from enjoyment at the childhood level of sporting activities to competitiveness during the teenage years, generally leads to young athletes training harder and longer (Shanmugam and Maffulli 2008). The physiological makeup and training responses of adolescents is markedly different from that of mature adults as they are still developing physically and mentally (Wells and Norris 2009). A mix of training methods is required to obtain the optimal training effect whilst the athlete continues to grow and mature. Youth athletes need to undertake strength training, metabolic conditioning and neuromuscular training appropriate to the different phases of growth and maturation, which makes the monitoring of training load even more critical to minimise the risk of injury and overtraining (Kutz and Secrest 2009).

Adolescents are worthy of special consideration because they are often participating in various team and individual sports with high physical demands in the absence of workload monitoring (Hartwig, Naughton et al. 2008). Further investigation of this cohort is required to better understand current training practices of youth athletes relative to player performance, injury and participation longevity (Finch, Donohue et al. 2002). Only a limited number of studies have given insight into the training loads of youth athletes (Finch, Donohue et al. 2002; Dennis, Finch et al. 2005; Hartwig, Naughton et al. 2008; Hartwig, Naughton et al. 2009), with no published works within the junior AF cohort. Attention has focused previously on the injury rate of junior AF players without investigation into the effect of training modalities and causes of
subsequent injury (Grimmer and Williams 2003). Investigations into the load, stress and recovery in adolescent rugby union players during a competitive season found value in serially monitoring young athletes psycho-physiological responses to participation in sport with the use of a training diary/questionnaire (Hartwig, Naughton et al. 2009). In this study, athletes reported higher scores within their Recovery-Stress Questionnaire for athletes (REST-Q Sport) over the duration of a five day intensive rugby union championship tournament, providing insight into junior athletes’ load and stress when in a competitive environment (Hartwig, Naughton et al. 2009).

A high level of participation and supplementary activities outside of organised training and competition in their primary sport have shown to be the most significant predictor of sports injury occurrence in young adults (Van Mechelen, Twisk et al. 1996; Gianoudis, Webster et al. 2008). This suggests that the elite junior AF cohort may also require special attention when designing and monitoring training programs in both the individual and team setting. However, the optimal training load and how it is quantified requires clarification in elite junior AF practices.

2.2 Australian football

Australian football (AF) is the major football code played within Australia. It is a team based sport comprising of 22 players, with 18 on the field during a game, and a bench of four interchange players who can come on or off the ground at any time during a match. Players are typically characterised into three types of players: backs, midfield players or forwards. The game is played on an oval that usually ranges from 130-150m wide by 150-190m long (Veale and Pearce 2009b). A game lasts approximately 120 minutes in duration across four quarters. Teams are given a six minute break at quarter and three-quarter time and a 20 minute break at half time. The sport is contact in nature, with collisions and tackles occurring between opponents within the game as they fight to win possession of the ball and score for their team (Gray and Jenkins 2010).

Due to the high participation rate in AF across the nation, programs and competitions exist for young children and juniors. Adults compete in amateur or local leagues. Talented players between the ages of 14-18 are channelled through specific development pathway programs, such as regional academies and state development squads. These aid the transition for those who are drafted to one of the 18 current teams.
within the Australian Football League (AFL). Within Victoria, the pathway for elite junior AF player is through the TAC Cup. The league consists of 12 clubs, with six clubs recruiting players from the metropolitan Melbourne area, and six clubs recruiting players from the rural regions of Victoria.

A periodised model of a typical AF season for the elite junior player consists of four phases. Periodisation is the division of the training year into manageable phases with the objective of improving performance (Smith 2003). Athletes within an AF environment often complete a large volume of high intensity training during the pre-season period so their physical capacities are optimal for the competition season (Coutts, Reaburn et al. 2007). Within pre-season conditioning, the general preparation stage has a focus on developing a player’s base level of fitness. The variables of frequency, intensity and volume are progressively increased as fitness levels improve. As this happens, recovery procedures such as cryotherapy, flexibility, massage, appropriate rest and nutrition become more important and are also increased (Smith 2003). The general preparation phase usually runs from early November to early January and often has to break for four to six weeks during the school holiday break from mid-December to mid-January. During this break from formal training, strength and conditioning programs are still prescribed to the athletes to maintain their fitness levels. The specific preparation phase usually commences in mid-January and runs through until late March. A transition from higher volume fitness base work, to higher intensity, shorter, game specific distance running and longer rest efforts, including repeated sprint ability sessions, are prescribed. Up to five pre-season competition games are played within this period.

The in-season phase starts in April and finishes in August and consists of 18 home and away games. The top eight teams then contest final games over a four week period. Teams qualifying for the finals could play between one and four finals, extending their season into September. A team’s post-season period will run from August or September until early November, where active rest and maintenance of fitness are prescribed before the resumption of the next pre-season period in November. At the elite under 18 level, a player will train up to three designated nights a week during the pre-season period.

Once in-season, training occurs up to three times a week, but is varied in duration and intensity according to game demands. The first session is generally an
active recovery session where no to low physical workload is prescribed to the player. The remaining two training nights run for approximately 90-120 minutes duration, with focus on technical and game skill development and maintenance of fitness components. Differences in the number of formal training sessions between clubs can occur. There are three notable factors which can change the number of sessions a player will undertake at the TAC Cup level. First, rural clubs may conduct one formal group training session a week due to the large travel time and geographical distances some players need to undertake in order to attend. Second, if a player is not selected to play a TAC Cup match, they train and play with their local junior AF club. Third, players who attend a school which requires the player to train and play for their school as a priority, before their involvement within the TAC Cup program. All of these factors can alter the amount of physical load a player undertakes. No formal monitoring and analysis of the differences between those who do and do not play a TAC Cup game, or possible differences in weekly physical load between players of metropolitan and rural based locations has been completed. Additionally, no formal monitoring of those players who undertake school sporting and TAC Cup commitments has been investigated.

2.3 Game demands of Australian football

Training and game practices within AF has changed considerably over the past century; elite players are now full time professional athletes participating in a professional competition (Norton, Craig et al. 1999; Gray and Jenkins 2010). A needs analysis of the game indicates that players require a combination of the following physiological characteristics to play the game at the elite level: a solid aerobic base, speed, agility, repeated sprint ability, strength, reactive strength, power, and a good understanding of game tactics (Dawson, Hopkinson et al. 2004a; Young, Newton et al. 2005). The movement patterns of AF can be described as sporadic with repeated efforts of shorter high-intensity and sprinting efforts, over a base of lower intensity and jogging movements (Dawson, Hopkinson et al. 2004a; Dawson, Hopkinson et al. 2004b; Wisbey, Montgomery et al. 2009). High strain on the athlete’s aerobic and anaerobic systems take place due to high intensity movements occurring every 12 - 40 seconds (Veale and Pearce 2009b). Reductions in high intensity running efforts
(>14.4km/h) and their contribution to total distance have been found to be lower after the first quarter of a match, indicating a decrement in running performance over the course of an elite AF game (Coutts, Quinn et al. 2010b).

Differences in the game profiles of both elite junior and elite senior AF players have been reported (Veale, Pearce et al. 2007; Veale and Pearce 2009b; Coutts, Quinn et al. 2010b; Burgess, Naughton et al. 2012). Elite junior AF players do not experience the same game load volumes (10.4 – 16.7 km (position dependant)), as elite senior AF players in games (12.9 km) (Veale and Pearce 2009b; Coutts, Quinn et al. 2010b). It has been found that elite junior AF players are undertaking more high intensity work within games. From 2003 to 2009, the percentage of sprinting movements performed in games increased from 3.31% to 3.78% (Burgess, Naughton et al. 2012). Veale and Pearce (2007) investigated player movement patterns, position movement demands (Veale and Pearce 2009b) and the physiological responses during match play (Veale and Pearce 2009a) within the elite junior AF cohort, and recommended that specific training programs should replicate the game and positional demands.

2.4 Physical load

The physical load of competitive athletes can be assessed by retrospective questionnaires, diaries, physiological monitoring and direct observation of training behaviour (Hopkins 1991; Borresen and Lambert 2009). However, the accurate prescription of in-season training load to provide positive game day performance is still relatively unknown, as it is extremely difficult to measure and quantify all internal factors affecting an athlete (Smith 2003). No single physiological marker has been identified that can globally measure the fitness and fatigue response to exercise (Borresen and Lambert 2007; Borresen and Lambert 2009).

External physical load is derived from physical work a player undertakes within a game or training session. Internal physical load is derived from the physiological strain that an athlete experiences throughout a game or training session. External physical load is required to produce internal physical load (Impellizzeri, Rampinini et al. 2005). A coach must understand the mechanisms behind the prescription, outcomes and physiological stressors placed on the athlete from the prescribed training. Team sport environments require even greater attention to the physical load monitoring of athletes, as the use of group exercises are more common place and the external physical
load within a training session is often similar across the team (Bangsbo 1994; Bouchard and Rankinen 2001). The difficulty in quantifying physical load within a team sport is that every individual responds differently to the physical load and stressors placed upon them within a session due to differences in their physiological fitness and training response parameters (Impellizzeri, Rampinini et al. 2005). There is also evidence to suggest that several interactions regulate human exercise performance, which has been explained by Noakes’ central governor theory (Noakes 2000). The theory revolves primarily around the brain and central nervous systems role in regulating and terminating exercise before the occurrence of catastrophic biological failure within the athlete (Noakes 2000; Noakes, St Clair Gibson et al. 2005; Noakes 2011). Moreover, it suggests that physiological, metabolic and biomechanical factors may limit exercise performance under different exercise conditions, which makes quantifying physical load a rather challenging task (Noakes 2011).

Four variables can influence physical load; frequency of training, intensity of the training session, the type of training performed, and the duration of the training session. Frequency refers to the number of training or game sessions an athlete undertakes within the annual cycle (Smith 2003). Intensity is the designated work rate that conditioning movements or technical drills are performed at. Monitoring athlete intensity can be undertaken using objective methods such as heart rate values, or subjectively with the rating of perceived exertion (RPE) (Foster, Florhaug et al. 2001; Borresen and Lambert 2008a). The type of training performed is usually specific to the demands of the sport, but can vary depending on the periodisation phase to incorporate cross training activities. Session duration, a volume measure, is usually the most rigid of all these parameters within a team sport environment. Depending on the phase within the annual plan, the prescription of the number of sessions undertaken each week may vary, leading to differences in the duration between sessions. These variables can be manipulated to achieve the desired training and total physical load of the athlete and team. The total physical load outputs are usually dependent on the phase of the training cycle.

Studies have provided some insight into the training loads within youth sports such as men’s and women’s soccer (Impellizzeri, Rampinini et al. 2004; Alexiou and Coutts 2008), rugby league (Gabbett and Domrow 2007), rugby union (Hartwig, Naughton et al. 2008; Hartwig, Naughton et al. 2009), cycling (Pérez-Landaluce,
Fernández-García et al. (2002) and basketball (Gianoudis, Webster et al. 2008). These investigations have used HRM technologies, training and physical activity diaries and blood lactate measures. However, limited data exist about the optimal distribution of training load, how best to train an individual within a team, and the relationship of training load to total weekly physical load. An improved understanding of monitoring and quantifying load in adolescent athletes within the AF cohort is necessary, so best-practice training prescription principles can be developed and implemented to maximise performance outcomes and minimise the risk of injury over the career of the athlete (Hartwig, Naughton et al. 2009).

2.4.1 Overtraining

Training adaptations are a highly individual phenomena, and athlete variability warrants consideration when assessing training induced changes in performance (Borresen and Lambert 2009). It is well known that appropriately designed training plans can improve performance, and one of the main challenges facing the coach is in determining the point at which training becomes maladaptive (Coutts, Slattery et al. 2007). A consequence of the normal training process will see athletes experience short term minor fatigue and acute reductions in performance (Halson and Jeukendrup 2004). When training and total physical loads become excessive, a wide range of terms are used to describe the long term decrement in subsequent training and performance. Burnout, overexertion, staleness, overreaching and overtraining are terms used to describe physiological maladaptation from training (Kenttä and Hassmén 1998), which typically involve unfavourable cardiovascular, neuromuscular and/or hormonal changes and a subsequent decrease in performance (Earnest, Jurca et al. 2004). The literature in adults is comprehensive, but is lacking in youth athletes (Brenner, Small et al. 2007).

There is evidence that an increasing number of athletes are training more than once a day with minimal rest (Kenttä and Hassmén 1998; Brenner, Small et al. 2007). Youth athletes are often participating in more than one sport and exposed to multiple training sessions by their coaches and parents (Kutz and Secrest 2009). This makes players vulnerable to injury and overtraining, as they may not recognise the psychological or physical signs of strain from excessive training (Smith 2003; Kutz and Secrest 2009). For youth athletes, competition sport requires a well-constructed balance between competition, training and rest (Bricout, DeChenaud et al. 2011). No reliable
markers have been established to detect overtraining within an athlete, however the use of the RPE method in an applied exercise setting could be a valuable detection tool, as it takes into account the athletes’ reflection of their own body (Kenttä and Hassmén 1998).

2.5 Heart rate

Heart rate monitoring (HRM) is common practice in many elite sporting settings, most commonly in endurance based sports such as running and cycling (Jeukendrup and Van Diemen 1998; Earnest, Jurca et al. 2004; Borresen and Lambert 2007). The application of HRM is used extensively in the monitoring of training intensity and performance outputs of athletes (Majumdar, Khanna et al. 1997; Gamble 2004; Impellizzeri, Rampinini et al. 2005; Faff, Sitkowski et al. 2007; Little and Williams 2007; Bosquet, Merkari et al. 2008; Leiper, Watson et al. 2008; Matthew and Delextrat 2009). Technological developments in HRM and computer software allow coaches and fitness staff to gain valuable insight into an individual’s physiological intensity parameters, which has enabled more precise monitoring of an athlete’s internal physical load and health status (Achten and Jeukendrup 2003). Heart rate monitoring and session RPE have been used as a method to quantify training in team based sports such as soccer (Impellizzeri, Rampinini et al. 2004; Coutts, Rampinini et al. 2009).

Heart rate monitors that use chest electrode straps have been shown to be valid and reliable during physically demanding exercise, which has enabled investigations into the heart rate responses to exercise and training adaptations (Achten and Jeukendrup 2003; Borresen and Lambert 2008b). Compared with other indicators of exercise intensity, HR is easy to monitor, relatively inexpensive and can be used in most situations, including indoor environments. In addition, HRM could potentially play a role in the prevention and detection of overtraining (Achten and Jeukendrup 2003). It is well established that the autonomic nervous system has a major influence on HR (Laukkanen and Virtanen 1998). Heart rate can be used to indicate circulatory strain, and as a surrogate for energy expenditure (Drust, Atkinson et al. 2007). The increase of HR during exercise to near an athlete’s maximum value, is one of the surrogate indicators of maximal oxygen uptake, commonly known as VO$_{2\text{max}}$ (Faff, Sitkowski et
The use of HRM is one of the most popular indirect methods to estimate energy expenditure due to its low cost and ease of use (Garet, Boudet et al. 2005).

Whilst direct measurement of an athlete’s $HR_{\text{max}}$ within a laboratory is accurate, it is not always possible (Faff, Sitkowski et al. 2007). Additionally, the commonly used 220-age formula has been found to markedly overestimate $HR_{\text{max}}$ values of an individual, especially within the youth cohort (Faff, Sitkowski et al. 2007). This is where the use of a regression for age equation can be utilised, as it provides a more valid and closer match to an athlete’s true $HR_{\text{max}}$ value. Faff, Sitkowski et al. (2007), examined 1589 16-24 year old male youth athletes and formulated a regression for age formula which provided a lower standard estimation error and total error values of 2.7 and 7.9, respectively, compared to values of 3.5 and 11.4 when using the 220-age formula.

Although there are data to show that HR can be measured accurately during a range of physical activities, there is a lack of consensus on how to best interpret heart rate data when trying to quantify physical load (Lambert, Mbambo et al. 1998). Foster and Flourhaug (2001) investigated the method of quantifying intermittent exercise by summating the amount of time spent in a particular heart rate zone from their known maximal heart rate. Their findings suggested that this method may be a mode and intensity-independent method of quantifying training and game session load. However, a recent investigation undertaken by a cohort of Norwegian soccer players indicated that the use of time in HR zone was not valid for describing the effective training intensity (Algrøy, Hetlelid et al. 2011). This suggests that other factors need to be incorporated into quantifying physical load such as GPS TMA and session RPE.

### 2.5.1 Training impulse method

Training impulse (TRIMP) was proposed by Banister as a method to quantify a training session or unit dose of physical effort (Banister, Calvert et al. 1975). It is specific to endurance based sports as it uses steady state HR data as part of the equation. The concept of TRIMP is determined using training time and intensity (Banister 1990; Smith 2003). The method requires the training volume (training time) to be multiplied by training intensity (average heart rate) of the session. This method is easily transferable into a computer based spread sheet program for continual monitoring of a training plan. The limitation of this method is that it cannot accurately measure the
session load of non-aerobic events such as resistance training due to its stop-start nature (Borresen and Lambert 2009).

2.6 Rating of perceived exertion

Modern research with psychophysical ratings of sense of effort has led the American College of Sports Medicine to recommend RPE as a useful method or tool in the determination of exercise intensity (Williams and Eston 1989). The rating of perceived exertion was developed by Gunnar Borg, who developed the 6-20 RPE scale (Borg 1982). The concept of RPE was based on a subjective assessment of sensory information associated with the physiological responses to exercise (Dishman 1994). The rating of perceived exertion can be defined as the subjective measure of effort, strain, discomfort, and/or fatigue that is experienced during physical exercise (Robertson and Noble 1997). The RPE scale is considered relevant in exercise prescription due to its close relationship with heart rate and integration of other important strain variables. It is also a simple and inexpensive method of monitoring exercise intensity (Borg 1982; Little and Williams 2007).

2.6.1 Session rating of perceived exertion

Foster, Florhaug et al. (2001), developed a method to evaluate training load adapting the Ratio 1-10 scale. The session RPE scale, uses a ratio scaling method for determinations of overall session intensity (Borg 2001). The load associated with the game and training load of the session is expressed in arbitrary units (AU). The AU score is determined by the multiplication of the session volume in minutes, and the session intensity rating of a session RPE score the athlete provides (Borresen and Lambert 2009). The intensity rating is completed 30 minutes after the conclusion of the session (Foster, Florhaug et al. 2001). This global rating of a training session, allows for better assessment between differing types of training, including those where heart rate cannot be obtained.
<table>
<thead>
<tr>
<th>Rating number</th>
<th>Rating description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Rest</td>
</tr>
<tr>
<td>1</td>
<td>Very, very easy</td>
</tr>
<tr>
<td>2</td>
<td>Easy</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
</tr>
<tr>
<td>4</td>
<td>Somewhat hard</td>
</tr>
<tr>
<td>5</td>
<td>Hard</td>
</tr>
<tr>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>Very hard</td>
</tr>
<tr>
<td>8</td>
<td>-</td>
</tr>
<tr>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td>Maximal</td>
</tr>
</tbody>
</table>

**Figure 2.1:** Category Ratio 1-10 Rating of Perceived Exertion Scale
Reference: (Foster, Florhaug et al. 2001)

Session RPE has been acknowledged as a useful practical feedback tool in the areas of resistance training (Day, McGuigan et al. 2004; Sweet, Foster et al. 2004) and cardio-vascular training (Borresen and Lambert 2008a). It has been used in the sports of swimming (Wallace, Coutts et al. 2008; Wallace, Slattery et al. 2009), endurance based events such as running (Green, McIntosh et al. 2009), cycling (Borg and Kaijser 2006; Joseph, Johnson et al. 2008), along with intermittent based exercise for individuals who play team sports (Coutts 2003), such as basketball (Foster, Florhaug et al. 2001), rugby, (Kelly and Coutts 2007; Hartwig, Naughton et al. 2008) and soccer (Impellizzeri, Rampinini et al. 2004; Rampinini, Impellizzeri et al. 2007; Coutts, Rampinini et al. 2009; Algrøy, Hetlelid et al. 2011). Therefore, the session RPE method could be used as a game and training feedback tool within elite junior AF to quantify physical load.

As with all secular scales, the underlying mechanisms of session feedback are hard to completely understand with the use of one single scale (Borg 1982). Literature has suggested that RPE is dominated during low intensity exercise by local factors, and
as exercise intensity increases, central factors such as elevated blood lactate and respiration values play a more significant role (Dishman 1994). As AF has been described as a highly intermittent based sport, the utilisation of a global sessional intensity scale may have limitations as lower correlations are reported when compared with less intermittent, higher aerobic based training sessions within soccer (Little and Williams 2007; Alexiou and Coutts 2008). Further research is required to ascertain the physiological mechanisms behind cognitive perception of effort, which may clarify exactly what RPE represents (Borresen and Lambert 2009).

2.7 Global positioning systems

Recent developments in GPS technology provide an alternative method for the measurement of speed and position in sport (Townshend, Worringham et al. 2008). The GPS system was originally developed for use by the U.S. military and became available to the public in the mid 1990’s (Dobson and Keogh 2007). It utilises a network of 24 satellites that orbit the earth. The satellites emit radio signals in a unique code sequence, from which the GPS receiver decodes at the speed of light, to give an exact time and position, allowing for the calculation of distance and time (MacLeod, Morris et al. 2009). Using trigonometry, a minimum of four satellites are needed to calculate the position of the athlete wearing a GPS unit (Witte and Wilson 2004). Current GPS technologies enable a sampling rate ranging from 1 to 15 Hz (Hz = number of data points obtained per second). The application of GPS technology in a sporting environment enables the accurate tracking and monitoring of distance and running speeds covered by an athlete during a training or game session, superseding the previous options of direct coach observation or time motion analysis, with the use of video camera operation (Borresen and Lambert 2009). Software developments allow the sports scientist to measure a player’s movement in both real time and summary formats (Aughey and Falloon 2010).

Advancements in GPS technologies have made the receiver unit small and easy to wear, as it is the size of a mobile phone and weighs approximately 90 grams (MacLeod, Morris et al. 2009). The units are worn in a harness between the shoulder blades. The companies that have adapted this technology to the sports performance market have built in the capacity to log heart rate within the GPS data logger, when the
athlete wears a heart rate strap. This enables tracking of an athlete’s speed and heart rate within a session, something that has not been achievable previously (Larsson 2003).

There is potential to use GPS to quantify physical loads within individual and team sports (Borresen and Lambert 2009). Cricket (Duffield, Carney et al. 2009; Petersen, Pyne et al. 2009; Petersen, Pyne et al. 2010), hockey (MacLeod, Morris et al. 2009), netball (Higgins, Naughton et al. 2009), orienteering (Larsson and Henriksson-Larsen 2001), rugby league (Hartwig, Naughton et al. 2008), rugby union (Cunniffe, Proctor et al. 2009) soccer, (Barbero-Álvarez, Coutts et al. 2010) tennis (Reid, Duffield et al. 2008) and even thoroughbred horse racing (Curtis, Evans et al. 1997; Hebenbrock, Due et al. 2005; Kingston, Soppet et al. 2006) have used GPS TMA to gain further insight into competition and training demands. Specific to AF, the quantification of movement demands and match running performance using GPS technology have been investigated within the sub-elite and elite cohorts (Wisbey, Montgomery et al. 2009; Brewer, Dawson et al. 2010; Coutts, Quinn et al. 2010b). However, no current studies exist that have investigated the elite junior AF player using GPS technology to monitor physical loads, in particular, training load.

Global positioning system TMA monitoring provides the sports scientist with a plethora of live and summary TMA information on human performance movement patterns in a field setting (Wisbey, Montgomery et al. 2009). In the past, video TMA was conducted post game, taking many hours to record and review the physical movement demands of a single player (Roberts, Trewartha et al. 2006). The GPS TMA information can contribute to the development of sports specific training and conditioning programs (Deutsch, Kearney et al. 2007), as information relating to an athlete’s external training load output is available. If units are worn by multiple athletes within a team, comparisons of the individual physiological responses to similar training regimes can be established, leading to an accurate means of being able to individually quantify training load within team sports (Larsson 2003).

2.7.1 Global positioning system validity and reliability

Recent studies into the validity and reliability of GPS devices revealed that the accuracy and reliability is reasonable for total distance (coefficient of variation (CV) <5%) and peak speeds (CV=2.3%) during high intensity, intermittent exercise within the team sport setting (Coutts and Duffield 2010a). Devices such as the GPS Spi Elite
model (GPSports, Canberra), which sample at 1 Hz, have been shown to be accurate in their measuring capacities of total distance to within 1.5% (MacLeod, Morris et al. 2009). Both these studies compared GPS against a criterion measure, which was a known measured distance incorporating changes of direction similar to those that occur within team sports, with researchers noting that the variation between devices may be caused by participants deviating from the measured track. Speed is calculated by dividing the changes in distance by the time between each logged position (Townshend, Worringham et al. 2008). Previous works into the determination of true speed over ground when cycling, revealed that a 1 Hz unit will measure 45% of the true speed within 0.2ms\(^{-1}\) and a further 19% within 0.4ms\(^{-1}\) (Witte and Wilson 2004). It has been demonstrated that GPS is a valid and reliable measure of estimating repeated speed efforts over distances of 15 to 30 meters (Barbero-Álvarez, Coutts et al. 2010).

2.8 Summary

Technological developments of physiological assessment equipment have provided smaller and more portable units, allowing athletes to be accurately monitored when training or playing sport. Knowing precise physical loads of athletes will lead to a greater understanding of the internal and external training load mechanisms, as accurate game and training distances, and subsequent breakdown of TMA characteristics within individual and team sport athletes are now possible. With the continual improvements in GPS, HRM and data analysis software technology, integrated physical load monitoring is possible. The utilisation of both objective GPS TMA and HRM measures, and a subjective psychophysiological feedback method in session RPE, could work synergistically to map individual work intensity and volume parameters within games and training across the annual plan. The information could be used to quantify physical loads within elite junior AF players. The aim of this thesis was to address the quantification of physical load within the elite junior AF cohort using the methods of individual training diaries, GPS TMA and HR.
Chapter three: Methods

3.1 Research design

This study used a prospective longitudinal research design. Data was collected between May and August, over a 19 week period during the 2009 under 18 Transport Accident Commission Cup (TAC Cup) competition.

3.2 Study overview

Figure 3.1: Study overview
3.3 Participants

Four TAC Cup clubs agreed to participate in the study. A total of 63 male AF players drawn from two metropolitan (clubs one and two) and two rural clubs (clubs three and four) within the TAC Cup competition participated in the study. All participants received a letter explaining the aims and requirements of the study and gave informed consent. Ethics approval was given by the Human Research Ethics Committee of Deakin University (HEAG-H 40_09), and the study was approved by Football Victoria. Parental consent was obtained for participants under the age of 18 years.

3.4 Organisation of study

Serial monitoring of players with the use of training diaries, saw a total of 1046 weeks of training diary data collected from 63 participants across four clubs (aim one). The collection of GPS and HRM data were obtained during both game and training conditions. A total of 36 game session files were collected from the three clubs across four games within the 2009 TAC Cup competition season. A total of 187 training session files were collected from the three clubs across 19 training sessions (aims two and three). One rural club (club four) collected insufficient GPS TMA & HRM data and were excluded from aims two and three of the analysis. Both game and training sessions were conducted on outdoor ovals. The training sessions were part of the in-season periodisation phase prescribed by the coach, with no input from the researcher.

3.5 Quantification of physical load

Subjective measures of physical load were obtained with training diaries, where participants recorded training time and a session rating of perceived exertion (RPE) using the category ratio 1-10 RPE scale (CR1-10). Two objective methods were used to establish training and game loads of elite junior AF players. Objective measures of external physical load were obtained via individual GPS TMA. Measures of internal physical load were obtained through HRM.
3.6 Training diary

Players completed an individual training diary where they subjectively recorded their mean intensity using RPE (CR1-10 scale) and time duration for each training and game session, approximately 30 minutes post session. This formed the session RPE score \([\text{RPE} \times \text{session time (min)}]\), which was used to calculate a subjective estimate of session load (Foster, Florhaug et al. 2001). Players’ total physical load requirements within the specific areas of game and training, as well as strength and conditioning activities were recorded relevant to their TAC Cup football, school/club football and other sport. Additionally, school physical education and other recreation activities were included within the diary. The activity type was categorised as weight bearing or non-weight bearing activity. This enabled an analysis of the breakdown between the variables of total weight bearing load and total non-weight bearing load, within the overall total weekly physical load. Players were instructed to complete the diary on a daily basis. Recall of the week’s events was undertaken with a research assistant, where a recall of all physical activity sessions in the previous seven days was verified.

3.7 Time motion analysis

Players were fitted with an individual GPS TMA data logger unit (SPI elite unit, GPSports, Fyshwick, Canberra) during game and training sessions. An undergarment that housed the unit within a pouch between the shoulder blades was worn by the player. The units logged the key time motion analysis variables of speed, low intensity activity (zones 1-3 representing TMA of 0-14.4 km/h), high intensity running (zones 4-6 representing TMA above 14.4 km/h), and individual zonal data of the player (Table 3.1). Data was obtained at a rate of 1Hz. Please refer to section 2.7.1 for the validity and reliability of these devices. Software processing of the GPS TMA and HRM data was undertaken within the Team AMS analysis software program (version 2.1.0.6. R1 2010 P2 GPSports, Canberra), which summarised heart rate and time motion analysis data. Files were edited to exclude major breaks within game and training sessions to provide a true representation of GPS TMA and HR characteristics. A major break was defined as a clearly identifiable time period of lost GPS signal or a period where no movement was undertaken. Typically these were the formal breaks within a game, or when players were taken indoors during the session.
Table 3.1: Summary of time motion analysis zones used to quantify external (GPS TMA) load

<table>
<thead>
<tr>
<th>Zone</th>
<th>Speed (km/h)</th>
<th>Speed description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone one</td>
<td>0 - 0.7</td>
<td>Standing</td>
</tr>
<tr>
<td>Zone two</td>
<td>0.7 - 7.0</td>
<td>Walking</td>
</tr>
<tr>
<td>Zone three</td>
<td>7.0 - 14.4</td>
<td>Jogging</td>
</tr>
<tr>
<td>Zone four</td>
<td>14.4 - 20.0</td>
<td>Running</td>
</tr>
<tr>
<td>Zone five</td>
<td>20.0 - 23.0</td>
<td>Higher-speed running</td>
</tr>
<tr>
<td>Zone six</td>
<td>23.0+</td>
<td>Sprinting</td>
</tr>
<tr>
<td>Zones one – three</td>
<td>0 – 14.4</td>
<td>Low intensity activity</td>
</tr>
<tr>
<td>Zones four – six</td>
<td>14.4+</td>
<td>High intensity running</td>
</tr>
</tbody>
</table>

Reference: (Coutts, Quinn et al. 2010b)

3.8 Heart rate

Players were fitted with a HRM strap (Polar Electro T34 transmitter, Finland) during game and training sessions. Players were instructed to moisten the electrode strap with water and firmly fit the strap slightly below the nipple line of their chest. Heart rate data was collected at a sampling rate of 1 Hz, and logged by the GPSSports Spi elite unit. Table 3.2 presents a summary of the HR analysis zones used to quantify internal load. Maximal heart rate (HR_{max}) was estimated according to the predictive equation established by Faff, Sitkowski et al. (2007) for youth and adult athletes during running. The formula of 209.9 - (0.73* age) was used to estimate HR_{max} of each player (Table 3.3).
Table 3.2: Summary of heart rate analysis zones used to quantify internal (HR) load:

<table>
<thead>
<tr>
<th>HR zone</th>
<th>Heart rate (% of HR$_{\text{max}}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone one</td>
<td>50-60</td>
</tr>
<tr>
<td>Zone two</td>
<td>60-70</td>
</tr>
<tr>
<td>Zone three</td>
<td>70-80</td>
</tr>
<tr>
<td>Zone four</td>
<td>80-90</td>
</tr>
<tr>
<td>Zone five</td>
<td>90-100</td>
</tr>
<tr>
<td>Zone six</td>
<td>100+</td>
</tr>
</tbody>
</table>

Reference: (Foster, Florhaug et al. 2001; Coutts, Quinn et al. 2010b)

Table 3.3: Summary of predicted HR$_{\text{max}}$ values across participants (N=53):

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Predicted HR$_{\text{max}}$ value (bpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>17 (N=12)</td>
<td>198</td>
</tr>
<tr>
<td>18 (N=37)</td>
<td>197</td>
</tr>
<tr>
<td>19 (N=4)</td>
<td>196</td>
</tr>
</tbody>
</table>

HR$_{\text{max}}$ = maximal heart rate, bpm = beats per minute

3.9 GPS TMA and HRM zone selection rationale

Zones 4-6 for GPS TMA (Table 3.1) and HRM (Table 3.2) were selected because they typified the work undertaken at a higher intensity compared to zones 1-3, which is defined within the literature as low intensity activity. The breakdown of these zones have been used in previous research within AF (Coutts, Quinn et al. 2010b) and outdoor team sports (Foster, Florhaug et al. 2001; Mohr, Krstrup et al. 2003; Impellizzeri, Rampinini et al. 2004; Rampinini, Coutts et al. 2007; Rampinini, Impellizzeri et al. 2009; Coutts and Duffield 2010a).

3.9.1 Session RPE data selection rationale

Previous research has reported that there are typically stronger relationships when using the session RPE method (RPE x session time) to assess the global intensity of a session, compared to an RPE score alone (Foster, Florhaug et al. 2001; Impellizzeri, Rampinini et al. 2004; Alexiou and Coutts 2008; Henderson, Gastin et al. 2008).
Additionally, the intermittent running profile description of AF, sees similarities to the sports of soccer and rugby union which have used the session RPE method to serially monitor team sport athletes (Gabbett and Domrow 2007; Alexiou and Coutts 2008; Coutts, Rampinini et al. 2009).

3.10 Data analysis

Individual player diary data from participants across the four clubs were analysed to provide a representative sample across the TAC Cup competition for aim one. An investigation into the differences of total weekly activity in players who did and did not play a TAC Cup game in any given week was conducted to understand the differences in physical load. The differences in physical load between players from metropolitan and rural clubs were assessed using an independent samples \( t \)-test. Preliminary analyses were conducted to assess the assumption of equality of variances using Levene’s test. Variances were either reported as equal or not equal depending on the result of the Levene’s test.

Individual player diaries, GPS TMA and HRM data from participants across three clubs were analysed to provide a representative sample across the TAC Cup for aims two and three. Club four was excluded due to insufficient data. To determine the typical physical demands elite junior AF players were subjected to within competition and training environments (aim two), a descriptive analysis was conducted on the key GPS TMA and HRM summary variables. Analyses comparing the statistical differences between individual player game and training sessions was not evaluated due to the low amount of data available where a player had both training and game sessions recorded within the same week.

After initial assessment of relationship strengths (refer to appendix two for values), a final multiple linear regression model incorporating the variables of high intensity running, and minutes spent between 50-80% of predicted HR\(_{\text{max}}\) was investigated to assess the ability to predict session RPE scores (aim three). Where differences between variables needed to be assessed, a one-way analysis of variance (ANOVA) was performed. Statistical significance was set at \( p<0.05 \). Statistical package for the social sciences (SPSS) software (Version 17.0 SPSS Inc., Chicago Ill) was used for all statistical calculations. Data are presented as mean, ± standard deviation (SD) and range.
Chapter four: Results

4.1 Participant descriptives

Descriptive analyses of players’ age, height and weight were similar in the four clubs (Table 4.1). A one way analysis of variance (ANOVA) showed no significant differences between the clubs in each of the three variables.

<table>
<thead>
<tr>
<th>Table 4.1: Descriptive data of participants (mean ± SD).</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>Club one</td>
</tr>
<tr>
<td>Club two</td>
</tr>
<tr>
<td>Club three</td>
</tr>
<tr>
<td>Club four</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

4.1.1 Weekly physical load when selected to play a TAC Cup match, or not selected to play a TAC Cup match within any given week

Results from individual variables, the total weekly physical load exposure, and the differences between players who were selected to play a TAC Cup match or not selected to play a TAC Cup match using a training diary are presented in Table 4.2.
Table 4.2: Weekly physical load (in minutes) of elite junior Australian football players obtained from training diaries who played a TAC Cup game and those who did not within any given week.

<table>
<thead>
<tr>
<th></th>
<th>Physical load in minutes when selected to play a TAC Cup game (Mean ± SD)</th>
<th>Range</th>
<th>Physical load in minutes when not selected to play a TAC Cup game (Mean ± SD)</th>
<th>Range</th>
<th>T</th>
<th>Df</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAC match</td>
<td>109 ± 21</td>
<td>15 - 120</td>
<td>112 ± 99</td>
<td>0 – 420</td>
<td>-7.95</td>
<td>661</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>TAC training^</td>
<td>155 ± 65</td>
<td>0 - 360</td>
<td>112 ± 99</td>
<td>0 – 420</td>
<td>-7.95</td>
<td>661</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Other football^</td>
<td>55 ± 86</td>
<td>0 - 480</td>
<td>136 ± 152</td>
<td>0 – 640</td>
<td>9.93</td>
<td>602</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Other weight bearing load^</td>
<td>91 ± 86</td>
<td>0 - 480</td>
<td>119 ± 132</td>
<td>0 – 1080</td>
<td>3.73</td>
<td>658</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Non-weight bearing load#</td>
<td>25 ± 57</td>
<td>0 - 300</td>
<td>23 ± 46</td>
<td>0 – 300</td>
<td>-0.59</td>
<td>1050</td>
<td>.152</td>
</tr>
<tr>
<td>Total weight bearing load^</td>
<td>410 ± 126</td>
<td>110 - 930</td>
<td>366 ± 200</td>
<td>0 – 1200</td>
<td>-4.04</td>
<td>648</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Total physical load^</td>
<td>434 ± 129</td>
<td>120 - 930</td>
<td>388 ± 192</td>
<td>0 – 1200</td>
<td>-4.32</td>
<td>675</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

^ Equal variances assumed
# Equal variances not assumed
Elite junior AF players who played a TAC Cup game (Table 4.2) showed a mean total weekly physical load of 434 minutes. Players who did not play a TAC Cup game had a total weekly physical load of 388 minutes. A significant difference (p<.001) in the total weekly physical load between the groups was found. Players who play a TAC match undertook a greater amount of time in TAC training, whilst those who were not selected to play a TAC Cup game spent a larger proportion of their weekly physical activity in other football and other weight bearing load activities. The majority of the total weekly physical load undertaken by both groups was weight bearing.

4.1.2 Weekly physical load comparisons between players from metropolitan and rural clubs

Results into the differences between variables and total weekly physical load undertaken by metropolitan and rural zoned players using an individual training dairy are presented in Table 4.3.
Table 4.3: Weekly physical load differences (in minutes), of elite junior Australian footballer players obtained from training diaries who are zoned within a metropolitan or rural TAC Cup club.

<table>
<thead>
<tr>
<th></th>
<th>Weekly physical load in minutes of players from metropolitan clubs (Mean ± SD)</th>
<th>Range</th>
<th>Weekly physical load in minutes of players from rural clubs (Mean ± SD)</th>
<th>Range</th>
<th>T</th>
<th>Df</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of weeks data ^</td>
<td>8.6 ± 4.8 (N=511)</td>
<td>1 – 17</td>
<td>8.5 ± 4.7 (N=539)</td>
<td>1 – 17</td>
<td>-.167</td>
<td>1048</td>
<td>.867</td>
</tr>
<tr>
<td>TAC match#</td>
<td>115 ± 16 (N=284)</td>
<td>10 – 120</td>
<td>103 ± 25 (N=347)</td>
<td>15 – 120</td>
<td>-7.18</td>
<td>600</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>TAC training^</td>
<td>184 ± 62 (N=465)</td>
<td>20 – 390</td>
<td>132 ± 66 (N=474)</td>
<td>30 – 420</td>
<td>-12.46</td>
<td>937</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Other football^</td>
<td>207 ± 114 (N=183)</td>
<td>30 – 640</td>
<td>165 ± 116 (N=312)</td>
<td>30 – 510</td>
<td>-3.925</td>
<td>493</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Other weight bearing load#</td>
<td>148 ± 108 (N=370)</td>
<td>20 – 1080</td>
<td>121 ± 74 (N=406)</td>
<td>15 – 460</td>
<td>-3.95</td>
<td>649</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Non-weight bearing load^</td>
<td>67 ± 62 (N=110)</td>
<td>10 – 300</td>
<td>85 ± 74 (N=188)</td>
<td>10 – 285</td>
<td>2.12</td>
<td>296</td>
<td>.035</td>
</tr>
<tr>
<td>Total weight bearing load#</td>
<td>415 ± 169 (N=508)</td>
<td>30 – 1200</td>
<td>375 ± 138 (N=531)</td>
<td>30 – 840</td>
<td>-4.17</td>
<td>980</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Total physical load#</td>
<td>428 ± 172 (N=509)</td>
<td>40 – 1200</td>
<td>400 ± 143 (N=538)</td>
<td>50 – 870</td>
<td>-2.95</td>
<td>990</td>
<td>.003</td>
</tr>
</tbody>
</table>

^ Equal variances assumed
# Equal variances not assumed
Measures of physical load obtained from training diaries from metropolitan and rural clubs (Table 4.3) showed significant differences (p < .001) for TAC match, TAC training, other football, other weight bearing load and total weight bearing load. Non-weight bearing load (p = .035) and total weekly physical load were also significant (p = .003). There was no significant difference in the number of weeks in training (p = .867). Results from the weekly physical activity profiles suggested that players from metropolitan clubs undertake a higher total weekly physical load compared to players from rural clubs.

4.1.3 Weekly physical load profiling summary

Results from the individual training diaries indicated a significantly higher amount of total mean total weekly physical load for players who were selected to play a game of TAC Cup football compared to players who did not (434 ± 129 v 388 ± 192 minutes) (p < .001). Players from metropolitan clubs had a significantly higher total weekly physical load compared to players from a rural club (428 ± 172 v 400 ± 143 minutes) (p < .001). An overwhelming majority of physical load activities were in the form of weight bearing activities.
4.2 Game and training loads

The sample used to gain insights into the physical load within game and training sessions using GPS TMA and HRM technologies, consisted of 36 game and 187 training files collected across 23 sessions from 53 participants.

4.2.1 External load measured during a game

Table 4.4: Time motion analysis information of players during a game (N=36 in four games).

<table>
<thead>
<tr>
<th></th>
<th>Mean ± SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Match time (min)</td>
<td>103 ± 12.5</td>
<td>63 – 119</td>
</tr>
<tr>
<td>Total distance (m)</td>
<td>10892 ± 2210</td>
<td>6676 – 15110</td>
</tr>
<tr>
<td>Average distance per minute (m)</td>
<td>106 ± 17</td>
<td>68 – 134</td>
</tr>
<tr>
<td>Low intensity activity(0-14.4km/h) (m)</td>
<td>7968 ± 1520</td>
<td>4614 – 10159</td>
</tr>
<tr>
<td>High intensity running (&gt; 14.4km/h) (m)</td>
<td>2495 ± 1004</td>
<td>1429 – 5126</td>
</tr>
<tr>
<td>Very high intensity running (&gt; 20.0km/h) (m)</td>
<td>731 ± 731</td>
<td>251 – 1665</td>
</tr>
<tr>
<td>Peak speed (km/h)</td>
<td>27.9 ± 1.8</td>
<td>24 – 31</td>
</tr>
<tr>
<td>Number of sprints (&gt; 23.0km/h)</td>
<td>15.1 ± 9.0</td>
<td>3 – 37</td>
</tr>
<tr>
<td>Average sprint time (s)</td>
<td>2.2 ± 0.5</td>
<td>1 – 3</td>
</tr>
<tr>
<td>Average sprint distance (m)</td>
<td>15.3 ± 3.5</td>
<td>7 – 24</td>
</tr>
</tbody>
</table>

Analysis of objective game distance data showed that elite junior AF players cover approximately 10.9 km a game, across 103 min (Table 4.4). The mean low intensity activity accounted for 8 km with high intensity running accounting for 2.5 km. A mean of 106 m per minute was covered by players when playing a competitive game. The mean peak speed achieved by players within a game was 27.9 km.
4.2.2 Internal load measured during a game

Within a game, elite junior AF players recorded an average HR of approximately 80% of their predicted HR\(_{\text{max}}\). Peak HR values within a game revealed a mean of 195 bpm (Table 4.5), indicating that a player would generally find themselves working at an intensity close to that of their predicted HR\(_{\text{max}}\) value at some stage within a game. It was found that players spent close to one hour at an intensity above 80% of their predicted HR\(_{\text{max}}\), and just under 25 minutes above 90% of their predicted HR\(_{\text{max}}\) within a game.

Table 4.5: Heart rate data of players during a game (N=27 across four games).

<table>
<thead>
<tr>
<th></th>
<th>Mean ± SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR mean average (bpm)</td>
<td>159 ± 11</td>
<td>137 – 178</td>
</tr>
<tr>
<td>HR(_{\text{peak}}) (bpm)</td>
<td>195 ± 10</td>
<td>178 – 210</td>
</tr>
<tr>
<td>HR zones 1-3 (min) (50-80% pred HR(_{\text{max}}))</td>
<td>40.2 ± 18.9</td>
<td>13 – 96</td>
</tr>
<tr>
<td>HR zones 4-6 (min) (above 80% pred HR(_{\text{max}}))</td>
<td>59.1 ± 20.0</td>
<td>15 – 99</td>
</tr>
<tr>
<td>HR zones 5+ (min) (above 90% pred HR(_{\text{max}}))</td>
<td>24.4 ± 21.5</td>
<td>0 – 75</td>
</tr>
</tbody>
</table>
4.2.3 External load measured during training

Objective training distance data revealed that the mean distance covered by elite junior AF players was 6 km a training session (Table 4.6). Low intensity activity predominated with a mean distance of 4.5 km and high intensity running contributed a mean of more than 1.5 km. An average distance of 71.3 metres per minute was covered by players when training. The mean peak speed achieved by players within training was 27 km.

Table 4.6: Summary time motion analysis information of players during training (N=185 across 19 training sessions).

<table>
<thead>
<tr>
<th></th>
<th>Mean ± SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training time (min)</td>
<td>87.4±24.5</td>
<td>34 – 142</td>
</tr>
<tr>
<td>Total distance (m)</td>
<td>6037±1608</td>
<td>2430 – 10154</td>
</tr>
<tr>
<td>Average distance per minute (m)</td>
<td>71.3±15.8</td>
<td>39 – 124</td>
</tr>
<tr>
<td>Low intensity activity (0-14.4km/h) (m)</td>
<td>4503±1171</td>
<td>1723 – 7074</td>
</tr>
<tr>
<td>High intensity running (&gt; 14.4km/h) (m)</td>
<td>1532±710</td>
<td>117 – 4197</td>
</tr>
<tr>
<td>Very high intensity running (&gt; 20.0km/h) (m)</td>
<td>556±394</td>
<td>13 – 2195</td>
</tr>
<tr>
<td>Peak speed (km/h)</td>
<td>27±1.9</td>
<td>22 – 31</td>
</tr>
<tr>
<td>Number of sprints (&gt; 23.0km/h)^</td>
<td>10.6±7.4</td>
<td>1 – 48</td>
</tr>
<tr>
<td>Average sprint time (s)^</td>
<td>3.2±3.8</td>
<td>1 – 10.8</td>
</tr>
<tr>
<td>Average sprint distance (m)^</td>
<td>20.1±11.1</td>
<td>1 – 75</td>
</tr>
</tbody>
</table>

^ (N=177)
4.2.4 Internal load measured during training

Heart rate data revealed that players were exposed to an internal load relative to 70% of their predicted HR\textsubscript{max} across the duration of training. Players were exposed on average to 21 minutes of an internal load above 80% (zones 4-6) of their predicted HR\textsubscript{max}. Session HR\textsubscript{peak} values varied, with a mean of 190 bpm (Table 4.7), indicating that a player would be exposed to a relative internal load between 90-95% of their predicted HR\textsubscript{max} value at one point at least within a training session.

Table 4.7: Heart rate data during training (N=167 across 19 training sessions).

<table>
<thead>
<tr>
<th></th>
<th>Mean ± SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR mean (bpm)</td>
<td>137 ± 11</td>
<td>108 – 165</td>
</tr>
<tr>
<td>HR\textsubscript{peak} (bpm)</td>
<td>190 ± 10</td>
<td>155 – 214</td>
</tr>
<tr>
<td>HR zones 1-3 (min) (50-80% pred HR\textsubscript{max})</td>
<td>59.3 ± 21.0</td>
<td>13.4 – 111</td>
</tr>
<tr>
<td>HR zones 4-6 (min) (above 80% pred HR\textsubscript{max})</td>
<td>21.4 ± 13.1</td>
<td>0 - 56.3</td>
</tr>
<tr>
<td>HR zones 5+ (min) (above 90% pred HR\textsubscript{max})</td>
<td>5.4 ± 6.1</td>
<td>0 - 26.2</td>
</tr>
</tbody>
</table>

4.2.5 Game and training session physical load summary

The physical demands of elite junior AF during game and training sessions using GPS TMA and HRM demonstrated differences in both the external and internal physical load variables. Games were shown to typically last longer in duration compared to training sessions. Additionally, elite junior AF players were generally exposed to a higher external and internal physical load from a game compared to a training session.
4.3 Regression modelling

4.3.1 Subjective and objective results

The sample used for multiple regression analysis consisted of 150 training files collected across 19 sessions from 53 participants. The mean RPE score was 6.7, which suggested that player’s global perception of a session was considered to be generally ‘hard’ or ‘very hard’ (Table 4.8). Across a session, the elite junior Australian football player completed a mean high intensity running distance of 1532 metres, whilst spending approximately 59 minutes between 50-80% (zones 1-3) of their predicted HRmax value.

Table 4.8: Mean subjective assessment of competition and training load, and objective GPS TMA and HRM parameters across 19 sessions (N=150).

<table>
<thead>
<tr>
<th></th>
<th>Mean ± SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjective parameters:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RPE</td>
<td>6.7 ± 1.6</td>
<td>2 – 10</td>
</tr>
<tr>
<td>Time (min)</td>
<td>99 ± 28</td>
<td>15 – 140</td>
</tr>
<tr>
<td>Session RPE (AU)</td>
<td>676 ± 276</td>
<td>75 – 1080</td>
</tr>
<tr>
<td>Objective parameters:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High intensity running (m)</td>
<td>1532 ± 710</td>
<td>117 - 4197</td>
</tr>
<tr>
<td>HR zones 1-3 (min)</td>
<td>59 ± 21</td>
<td>13.4 - 111</td>
</tr>
</tbody>
</table>

AU: arbitrary units

4.3.2 Regression model

The relationship between physical load variables and self-reported session RPE from training sessions were explored using multiple regression analysis. Preliminary analyses were conducted to ensure no violation of the assumptions of normality, linearity, multicollinearity and homoscedasticity. Pearson correlation coefficients were
calculated to assess the suitability of each predictor factor for inclusion in the model. Only variables with Pearson correlation values above 0.3 and below 0.7 with the dependent variable were included in the final model (Pallant 2007) (see appendix two for full list of summary variables). Pearson correlation coefficients within the multiple regression model were calculated to assess the relationship between session RPE with the selected predictors of high intensity running, and time spent between 50-80% of predicted HR_{max}. Bivariate correlation of the selected predictor variables was calculated in order to assess multicolinearity between the variables of high intensity running and time spent between 50-80% of predicted HR_{max}. A relationship strength of R=.173 (p=.017) was found, indicating that both these predictor factors were suitable for use within the final regression model.

**Table 4.9:** Linear regression model of objective physical load summary data as a predictor of session RPE (N=150).

<table>
<thead>
<tr>
<th></th>
<th>High intensity running (m)</th>
<th>Time between 50- 80% pred HR_{max} (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson correlation with session RPE</td>
<td>.361*</td>
<td>.346*</td>
</tr>
<tr>
<td>B (unstandardised coefficient)</td>
<td>.124</td>
<td>3.763</td>
</tr>
<tr>
<td>Beta (Standardised coefficient)</td>
<td>.310</td>
<td>.292</td>
</tr>
<tr>
<td>p value</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>T value</td>
<td>4.174</td>
<td>3.935</td>
</tr>
</tbody>
</table>

*= Significant at p<0.01

In the final model the predictor variable of high intensity running recorded a higher beta and significance value (beta=.310, p<.001), than time spent between 50-80% of predicted HR_{max} (beta=.292, p<.001). The model as a whole explained 21.3% of the variance in session RPE (R=.461) F (2, 147) = 19.882, p<.001.
Chapter five: Discussion

This thesis presented data assessing the physical load of elite junior AF players using the methods of serial monitoring (training diary), GPS TMA and HRM technologies. This chapter will present a segmented discussion detailing how the findings of each aim contribute to the establishment and quantification of physical load within this cohort. The discussion will conclude with a future directions and recommendations section relevant to this area of research.

5.1 Self-reported physical load profiles (training diary)

The purpose of aim one was to describe the typical weekly physical load profiles of elite junior AF players using training diaries. Results obtained from the serial monitoring of training diary data across an entire season, demonstrated that those who played a TAC game, were typically exposed to a significantly higher total weekly physical load compared to those who did not play within the competition for that selected week (Table 4.2). These findings are similar to that of adolescent rugby union players, demonstrating that the weekly duration of sport and physical activity was higher in those playing at higher representative levels (Hartwig, Naughton et al. 2008). In the present study, those who played a TAC Cup game in any given week had a higher TAC Cup weekly training time, a larger contribution from the TAC Cup program, and a smaller range of total weekly physical load. These results can be partly explained by the additional TAC Cup squad training session that a player would undertake if selected to play in the TAC Cup competition for any given week, as those who were not selected typically returned to their local junior or school club to train. As the TAC Cup program is better structured in comparison to a local or school football program, additional time spent training compared to that of a local/school football environment would encompass a larger contribution to their total weekly physical load. The difference for those who did not play can be found in the other weight bearing load time, suggesting that players who did not play were exposed to additional physical load within their local or school football club, undertaking school sporting activities not relevant to AF, or were possibly in a return to play phase from injury. The distribution of total non-weight bearing load and total weight bearing load activities when expressed as a percentage of the total weekly physical load were similar (approximately 5% and 95% respectively), showing
that components of the training prescribed by coaches and the activity types undertaken by the player were similar across clubs. The distribution of total non-weight bearing load and total weight bearing load activities warrants further investigation, as the breakdown of activity type across a typical week appears imbalanced, and is coupled with a lack of evidence within AF or other youth sports to make comparisons against. This lack of comparable literature highlights the benefits of monitoring physical load of players using a training diary.

When comparing elite junior AF players from metropolitan and rural clubs, the results show that the typical metropolitan club player had a significantly higher total weekly physical load compared to the rural player (Table 4.3). Players from metropolitan clubs spent more time in all self-reported physical load parameters except for N-WBL. TAC Cup training and other football were shown to be much higher in metropolitan players when compared to rural players, indicating that there are factors associated with being a player zoned within a rural club. The increased time and distance for players in rural clubs to travel to their training venue is one factor contributing to this result. Club management reported that the whole team only trains together once per week due to the large distances that some players have to travel. Players from metropolitan clubs formally train together as an entire squad on at least two nights of the week. This has the potential to change the prescription of physical load by coaches who have the job of developing each player’s potential and readiness for an AF career, be it for amateur, local or elite AF. As stated by Finch et al. (2002), elite junior AF players need to be trained effectively to ensure that they are adequately prepared for competition. With rural players spending less time undertaking TAC training and other football, there is a risk that the development of rural players is not comparable to that of the metropolitan players due to lack of scheduled training.

There is evidence from the results presented to suggest that training diaries can identify players who are at risk from undertaking too little or large amounts of football specific and other physical activity. The total weekly load data presented does indicate that some players were undertaking a low weekly physical load that would not allow for individual fitness maintenance throughout the season to be match fit on a weekly basis. A low level of training and physical activity has potential repercussions on player development and transition into higher levels of AF. Additionally, the results also indicate that there could be a minimal number of players who were undertaking a larger
than normal amount of physical load. For those players found to be undertaking a large amount of physical load, especially those who were participating in additional sporting activities outside of the TAC Cup program, the diary can assist in the identification of players who may be candidates for over-reaching and overtraining.

5.2 TAC Cup game and training demands (GPS TMA & HRM)

The purpose of aim two was to describe the typical physical demands an elite junior Australian football player is exposed to within game and training environments using GPS TMA and HRM technologies. Comparative profiles of the game and training demands of other team sports are limited in adolescent team sports (Abdelkrim, El Faza et al. 2007; Hartwig, Naughton et al. 2008; Ben Abdelkrim, Castagna et al. 2010). Specific to elite junior AF, Finch et al. (2002) recommended that a more comprehensive profile of playing habits was required. Findings from the current investigation indicated that players within the elite junior AF cohort were typically exposed to a higher physical load in the game environment, for both external (GPS TMA) and internal (HRM) load parameters, compared to the in-season training environment. The key physical load variables of session time, total distance, distance per minute, high intensity running, number of sprints, mean HR and minutes spent above 80% of predicted HRmax, were all higher in games in comparison to the training session data (Tables 4.4 - 4.7). This is in line with previous findings within elite and elite junior level AF and rugby union (Dawson, Hopkinson et al. 2004b; Veale, Pearce et al. 2007; Hartwig, Naughton et al. 2008; Brewer, Dawson et al. 2010). This finding is expected as coaching and fitness staff view the game as the most physically demanding session of the weekly cycle. Typically, training sessions early in the week are lower in intensity as players recover from the game, and training sessions later in the week are generally lower in volume as the player prepares for the game (Dawson, Hopkinson et al. 2004b).

Even though AF is a team based sport, player variability will occur in the external and internal load profiles due to differences in players’ physiological composition (Impellizzeri, Rampinini et al. 2004). Factors such as the player’s game position, the type of running movements required for that position, training age and adaptation to training stimulus will have an effect on the amount of physical load (Hartwig, Naughton et al. 2008; Veale and Pearce 2009b; Brewer, Dawson et al. 2010; Gray and Jenkins 2010). Variability in the training loads between clubs was observed.
The researcher had no control over training structure and content. Differences are likely a result of differing coaching techniques, session aims, the amount of time spent training, the breakdown of skill and conditioning drill prescription and tactical components of the prescribed training session. Similar findings investigating the differences between game and training sessions have been reported in rugby union for the TMA variables of total distance, low intensity activity and high intensity running (Hartwig, Naughton et al. 2008; Hartwig, Naughton et al. 2011).

5.2.1 Game and training external load demands (GPS TMA)

The mean duration of a game (103 min) was longer compared to training (87 min). In comparison to elite AF players, the game time was similar (99-104 min, position dependent) and training time was shorter (47-66 min) (Dawson, Hopkinson et al. 2004b; Wisbey, Montgomery et al. 2009). Training time was in a similar range when compared to adolescent rugby union players with a reported range of 58-93 min depending on squad level (Hartwig, Naughton et al. 2008). As the TAC Cup program is run part time compared to that of a full time program for the elite AF player, the differences in training times are to be expected. Possible reasoning for this would be that the elite club environment could hold a larger number of shorter duration based sessions across the typical weekly cycle compared to that of a TAC Cup club.

The players typically covered a greater distance during a TAC Cup game compared to a training session (10.9 v 6.0 km). Previous findings indicate the range of total distances covered by players within a TAC Cup game to be between 9.2 and 11.9 km (Veale, Pearce et al. 2007), which is similar to the findings of our investigation. Furthermore, a recent investigation of elite AF players during a game showed the total mean distance to be around 12.9 km (Coutts, Quinn et al. 2010b), which is more than the present study. The majority of distance covered by players in game and training was categorised as low intensity activity. A recent review of the AF literature by Gray and Jenkins (2010), on match analysis and the physiological demands of elite AF stated that previous investigations in AF showed players spent most of their time undertaking low intensity activity, which is similar to our findings. Various factors can influence external physical load variables within a game, such as match duration, fitness, motivation, chance of obtaining possession, and the game plan of both teams may act to

Peak speed values from both the game and training data sets showed little difference overall, indicating that at times, efforts within training match the efforts required to be performed within games. There was a noticeable difference in the number of sprints performed by players in games compared to training. Sprints (classified as TMA above 23 km/h) within games were generally shorter in time and distance but a higher mean number were performed in comparison to training. A possible explanation for this is that training is more structured over larger parts of the ground and often not restricted by positional and defensive aspects. Fitness objectives are also sometimes built into a drill increasing the sprinting distance and length.

5.2.2 Game and training internal load demands (HRM)

An important application of HRM is to evaluate the intensity of the exercise performed. There is limited literature reporting the internal load measures of HR responses within AF games and training, with only one published investigation specific to the elite junior AF cohort (Veale and Pearce 2009a). However, their investigation only reported match data, not allowing comparisons with training data. Mean HR’s within games and training sessions in this study showed noticeable differences. Games reported a mean average HR of 159 bpm, compared to training that reported a mean average HR of 137 bpm.

Comparative elite junior AF player research undertaken by Veale and Pearce (2009a), who investigated game sessions during the pre-season period, reported that players spent the longest time in the 85-95% HRmax range. This is similar to the findings within this thesis, as the majority of a player’s internal load during a game was above an intensity of 80% (zones 4-6) of their predicted HRmax value within a game (59 min). Unfortunately, their work did not report any time spent in zone HR values, which does not allow for a more accurate comparison against our findings. Similar findings were shown in the HRpeak values, where games demonstrated a higher mean HRpeak compared to training sessions. In addition, a smaller range of player’s HRpeak values in games was found, which is to be expected due to the higher external load demands placed on players within a game.

During games players spent a mean of 59 min working above 80% of their predicted HRmax (Table 4.5), in comparison to training where players were exposed for
21 min (Table 4.7). These differences can partly be explained by the duration of a game (103 ± 13 min) compared to a training session (87 ± 25 min). Positional differences may also play a part in explaining these differences, as it has been reported that certain positions will require more working efforts than resting efforts (Dawson, Hopkinson et al. 2004a; Veale, Pearce et al. 2007). The controlled environment of training, which sees coaches intermit proceedings to provide instructional feedback to players across a session, allows time for HR to decrease into the lower zones whilst players cease activity to take in coach feedback. In comparison, game sessions cannot be intermitted by the coaches and are uncontrollable, due to the competitive nature of the session where unpredictable low intensity activity and high intensity running take place in order to gain possession or stop the opposition from advancing the ball forward to score. To be able to purely replicate this within the training environment would prove difficult as each game imposes a differing set of physiological demands on the player and team.

5.3 GPS TMA and HRM predictors of session RPE

Aim three examined the relationships between objective training data (GPS TMA & HRM) and subjective feedback measures (s-RRE) within elite junior AF players. Research suggests that HR is a valid tool to help assist in the monitoring of physical load (Impellizzeri, Rampinini et al. 2004; Wallace, Coutts et al. 2008; Coutts, Rampinini et al. 2009; Manzi, D'Ottavio et al. 2010), yet GPS TMA parameters are yet to be reported against the session RPE method within the elite junior AF setting. Multiple linear regression analyses revealed that the model of best fit incorporated the predictors of high intensity running and time spent working at a HR between 50-80% of predicted HR_{max} against the set variable of session RPE score. This model was able to explain approximately 21% (R=.461) of the total variance associated with a player’s session RPE score. In comparison to soccer, our findings demonstrated a lower correlation compared to the combination of blood lactate measures and %HR_{peak} in small sided soccer games, where 57.8% of the total variance was associated with a players session RPE score (Coutts, Rampinini et al. 2009). As the factors from their investigation were single internal load measures, it makes accurate comparisons against the model in this thesis difficult as our final model used a combination of an external and internal physical load variable. Additionally Alexiou and Coutts (2008) reported
that stronger session RPE relationships could exist for measures taken during endurance based steady state exercise, compared to measures taken during intermittent exercise. The findings from our investigation demonstrated that factors not measured within this investigation were contributing to the players’ perception of session intensity, as only 21.3% of the variance was explained by two factors. Whilst the description of AF and soccer are similar in some aspects, soccer is defined as a non-contact sport in comparison to AF which has elements of contact such as tackling. In knowing this, it needs to be stressed that the overall demands are different and therefore the methods of assessing training and games need to vary accordingly. Therefore, the session RPE method may have limitations in assessing the overall perception within contact sports such as AF (Lambert and Borresen 2010).

High intensity running, a measure of training volume that takes into account the external load value of distance, was shown to be a stronger contributor to the overall model compared to the factor of time spent between 50-80% predicted HR\textsubscript{max} (intensity). This finding is in contrast to other research that has shown that intensity parameters derived from HR and blood lactate measures, are a better indicator of an individual’s perception of overall session intensity (Foster, Florhaug et al. 2001; Sweet, Foster et al. 2004; Egan, Winchester et al. 2006; Coutts, Rampinini et al. 2009). As this is the first investigation that has examined the applicability of accurate GPS TMA volume measures, specifically that of high intensity running, no clear conclusions can be made that high intensity running external load factors are a better indicator of session RPE scores than internal load zonal HR factors. Future investigations are warranted to better understand the applicability of summary and zonal GPS TMA and HRM parameters within elite junior and intermittent profile team sports such as AF.

Observations of the training session data indicate that players have to undertake highly intermittent work throughout a session, interspersed with periods of low intensity activity. It is possible that intermittent work may be responsible for increases in RPE scores in relation to HR measures. However, it has been reported that HRM is considered a relatively poor method of evaluating very high intensity exercises such as resistance training, high intensity interval training and plyometric training (Foster, Florhaug et al. 2001). Furthermore, literature suggests that the HR-RPE relationship deviates in accuracy once there is a shift to a higher proportion of the session being spent at a low or high intensity (Borresen and Lambert 2008a). As presented in aim two,
there was a large discrepancy between low intensity activity and high intensity running distances. Other factors may also affect the relationship between work rate and HR, including the exercise duration and the contribution of cardiovascular drift (Achten and Jeukendrup 2003). It has been suggested that increases in RPE scores are attributable to increases in the anaerobic contribution to energy production during intermittent training (Drust, Atkinson et al. 2007). It is plausible that the zonal HR analysis method could underestimate the overall intensity an athlete is actually working at, as the internal stress responses to sudden changes in high intensity running are not immediate (Achten and Jeukendrup 2003). Australian football involves frequent intermittent high intensity running bouts over varying distances. The short duration of these events means that a significant proportion of the exercise bout is spent with the heart rate fluctuating from a lower to a higher value without it reaching a steady state. Knowing this, it gives justification to support the findings of Algrøy (2011), who stated it is not possible for HR to accurately reflect the nonlinear impact of repeated, brief high intensity running periods followed by low intensity activity on perceived effort for the entire session. Future work should further assess the relationships between high intensity running obtained from GPS TMA and session RPE, which may lead to a better understanding of bridging the gap between immediate and delayed HR responses to high intensity running performance and perceptions of effort within intermittent profile sports such as elite junior AF. Other suggestions to help gain a better understanding of the physical loads imposed on this cohort include using accelerometer technology, which is typically embedded within the GPS unit and has been shown to detect changes or differences in physical activity levels in AF players (Boyd, Ball et al. 2011).

It is iterated that this thesis dealt with the developing athlete. During the adolescent period, maturation is a major confounding variable as significant changes during puberty make the prediction of performance difficult. Additionally, limited adolescent data exists, thus making accurate comparisons difficult, while comparisons with adult data are not ideal (Hartwig, Naughton et al. 2009). A limitation of training diary data is the potential for under or over reporting when wishing to determine total weekly physical load, as the session RPE score is partly psychophysiological in nature (Hopkins 1991). As mentioned previously within this thesis, the true underlying mechanisms of session feedback are hard to completely understand with the use of one single scale (Borg 1982). A multitude of factors outside GPS TMA and HR responses to
games and training sessions can affect the players’ perception of overall effort intensity and physical load exposure. These include an athlete’s sensitivity to the coaching style, personality trait, injury or illness state, recovery practices and internal stressors such as self, peer, school and parental pressure in addition to the adolescents physical development (Hartwig, Naughton et al. 2008; Hartwig, Naughton et al. 2009). As AF has been described as a highly intermittent based sport, the utilisation of a global sessonal intensity scale may have limitations as higher correlations have been reported within less intermittent, higher aerobic based training sessions within soccer (Little and Williams 2007; Alexiou and Coutts 2008). Further research is required to ascertain the physiological mechanisms behind our cognitive perception of effort, which may clarify exactly what RPE represents and its applicability for use within AF (Borresen and Lambert 2009).

Although technology has advanced, making it possible to accurately and reliably measure HR, there is still little knowledge about the application of HRM as a means of being able to provide accurate analysis of work, and assist in obtaining optimal training prescription to improve performance and adaptation (Achten and Jeukendrup 2003). It is a similar case for GPS TMA data, as there is still no clear and universal definition relating to the movement and speed zones when analysing the data. Due to the dynamic and multifaceted nature of elite junior athletes, the ability to serially monitor young players’ global responses to sporting participation is of value to the player, coaches and parents. Further benefit of using a training diary can be found in gaining a better understanding of individual load thresholds above which stress accumulates. Hence, the establishment of a best method of quantifying training load warrants further investigations within elite junior AF to help better understand the links between physical load, perceptions of training intensity, training adaptation and performance.
Chapter six: Conclusion

Poor documentation, insufficient availability to device technology, and a clear lack of evidence based guidelines to monitor physical load exposure within the youth athlete is one of the challenges faced by coaches, clubs, medical and sports science staff. This thesis provides an improved understanding of monitoring and quantifying physical load in the elite junior AF player including the type of physical activities undertaken, and the intensity and volume players are exposed to within the TAC Cup program for both game and training sessions.

The findings from this thesis support the use of training diaries within elite junior AF. It should also be acknowledged that total training time can also serve as a good basic method of monitoring physical load. With limited resources within the elite junior AF setting including that of staff, equipment and technology aids compared to that of an elite AF club, the ability to accurately monitor and track physical game and training loads of elite junior AF players is reduced. The training diary method enables identification of players who are at risk from undertaking continual weekly volumes of high or even low physical load, and in cases where players are participating in multiple sports. It provides an alternative means of monitoring of physical load status in the event of GPS TMA and HRM being unavailable. The training diary method is inexpensive, easy to setup, can be monitored with computer software, and tracked over short and long periods which can assist in effectively quantifying and monitoring physical load status. This is especially important within the elite junior AF cohort, as these players are part-time athletes and can be exposed to a high physical load without being aware of it.

The information obtained from GPS TMA and HR data within this thesis can collectively assist in the facilitation of best practice advice for player management, training and weekly physical load prescription. As this data is highly accurate and adjoining software programs are quite powerful from an analysis perspective, such data can aid in the development of specific training and conditioning programs across all phases of the annual plan. This includes utilising both the game and training data to prescribe appropriate return to play programming from injury and education of coaches of the typical volume and intensity of game and training sessions, which can enhance training drill prescription and specificity in relation to game demands.
The unique participation of elite junior AF players makes assessment of group trends difficult and justifies individual based scrutiny of physical load and psychophysiological feedback. While the complex interactions of physiological and psychological factors that contribute to the personal perception of physical effort may limit the use of session RPE as a sole method to quantify or prescribe overall session exercise intensity within elite junior AF, it remains an important option to monitor players competing at this level. Physical load monitoring with the aid of a training diary which enables a session RPE score to be obtained using session time (a useful indicator in its own right) can provide an alternative method for continual monitoring of global responses to physical load by the elite junior AF player. Whilst the use of objective physiological measurements such as GPS TMA and HRM may be a more accurate means of calculating and monitoring physical load, it is not readily available to most athletes and sporting clubs. It is in this situation where the session RPE method can be of use in monitoring physical load.
Chapter seven: Future directions and recommendations

Future research using the training diary method could help establish appropriate workloads that players should be exposed to and guide the prescription of progressive physical loads within the junior development period, leading to appropriate periodisation while balancing the risks of injury and overtraining. Examinations into the physical load exposure during the pre-season phase of training would give a greater understanding of the annual physical load exposure of the elite junior AF player. As adolescents may frequently participate in a number of sports and compete and train with several different teams representing various standards of competition, future longitudinal research investigating self-reported methods of physical load monitoring would be of interest. The relationships of physical load to injury risk and occurrence rates would benefit those who work with elite junior athletes.

A recommendation from the findings is to investigate the possible implementation of a training diary database for all players to use within the TAC Cup program. This information would be of benefit to coaching and support staff within the TAC Cup, recruiting staff, external parties such as local football clubs and schools which the player also attends. The system could link in with injury reporting which would allow for information to be collected and investigated on any relationships between training load and injury occurrence. This type of information would be of great use to an AFL club in the instance where a player is drafted as information on their physical load and previous injury history would be available upon consent, which could be used to assist in the design of their initial elite player training program. The development or use of an online database that collects and stores all physical activity data, including capacity to store other information such as GPS TMA and HRM training data would be of use. It could assist future studies into load monitoring and aid in guidelines that better manage the elite junior AF player and help identify the gap between elite junior and elite AF, and maximise participation longevity. As higher weekly physical loads were found for those who played a TAC Cup game in comparison to those who did not, a system as suggested could assist in establishing if the amount of physical load being undertaken by an individual has an effect on their development and performance. This recommendation is also relevant for players zoned within a rural club as the results indicate that typically, rural zoned players are
undertaking less documented physical load compared to the typical metropolitan club player. It is recommended that the diary be slightly amended to enable flexibility in assessing and monitoring the individual needs of the athlete. The inclusion of a flagging mechanism that highlights if a player is being exposed to what is deemed a too low or too high amount of weekly physical load would be of benefit. With advances in load monitoring devices, methods now exist that enable accurate assessment of movement demands and heart rate responses to physical work within individuals in team sports during training and game sessions. GPS TMA and HRM enables participation monitoring that could in the future, lead to systemic analysis of injury risk, overtraining and underperformance, which will enable a more in-depth understanding of the elite junior AF player. It is recommended that the utilisation of device technologies such as GPS TMA and HR be incorporated in situations where there is a clear need to better manage the physical load of players. Instances where this would be of benefit would be for players who are returning from injury and for the prescription and monitoring of specific training regimes. An additional application and recommendation of use for this technology would be to implement the use of these technologies to better monitor rural club players’ physical load who have logistical constraints in being able to attend training only once a week.

Future work within this cohort should ensure that initial and ongoing education about the RPE and session RPE method is undertaken to ensure the values accurately reflect the athletes’ global perception of the whole session, which would assist in assessing its applicability within the elite junior AF environment. It is recommended that coach and player education on the scales secular properties, its application and importance in monitoring physical load should be undertaken prior to its use. As the scale is designed for use as a global method of monitoring physical load, it needs to be understood that a single rating will not take into account all factors relating to training intensity, global perception of training and subsequent performance.
References:


Appendix

Appendix 1  Conference abstracts and poster presentations


### Appendix 2 Syntax data results for regression modelling (aim three)

#### Correlations

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Appendix 3 Ethics approval

DEAKIN UNIVERSITY

Human Ethics Advisory Group - Faculty of Health, Medicine, Nursing and Behavioural Sciences
221 Burwood Highway, Burwood Victoria 3125, Australia
Telephone: +61 3 2517 7444
Facsimile: +61 3 2517 7292
hmrp@deakin.edu.au

Memorandum

To: A/Prof J. J. Cook
   School of Exercise and Nutrition Sciences

From: Secretary - HEAG-H
   Faculty of Health, Medicine, Nursing, and Behavioural Sciences

Subject: HEAG-H 03/02: Measuring training loads and injury in TAC Cup football players

Approval has been given for A/Prof J. J. Cook, School of Exercise and Nutrition Sciences, to supervise this project for a period of 2 years from 22 April, 2009.

The approval given by the Deakin University HEAG - H is given only for the project and for the period as stated in the approval. It is your responsibility to contact the Secretary immediately should any of the following occur:

- Serious or unexpected adverse effects on the participants
- Any unanswerable changes to the protocol, including extensions of time
- Any events which might affect the continuing ethical acceptability of the project
- The project is discontinued before the expected date of completion
- Modifications that have been requested by other Human Research Ethics Committees

In addition, you will be required to report on the progress of your project, at least once every year and at the conclusion of the project. Failure to report as required will result in suspension of your approval to proceed with the project.

HEAG-H may need to audit this project as part of the requirements for monitoring set out in the National Statement on Ethical Conduct in Human Research (2007). An Annual Project Report Form can be found at http://www.deakin.edu.au/searchblades/index/humandr.htm which you will be required to complete in relation to this research. This should be completed and returned to the Administrative Officer in the HEAG-H, Dean's office, Faculty of Health, Medicine, Nursing & Behavioural Sciences, Burwood campus by Monday 23rd November, 2009 and when the project is completed.

Good luck with the project!

Steven Sawyer
Secretary
HEAG-H

cc Dr Paul Gustin, Prof Caroline Finch, Dr Jason Barry, Mr Dawson Kidgell, Mr Brenden Henderson

[Signature Redacted by Library]
**Appendix 4 Background questionnaire**

**BACKGROUND QUESTIONNAIRE:** QUANTIFICATION OF TRAINING LOAD IN ELITE JUNIOR ARF PLAYERS

### Section A: Demographic Information

1. Name:……………………………. D.O.B:……………………………
2. Height: ………cm Weight: ………kg
3. School currently attending: Name:………………… …………......... Suburb:………………… Year level: ………
4. Work
   Type of work……………………………………... Days and hours per week…………………………
5. Main competition position:
   □ Back □ Midfield □ Forward
6. How long have you been playing football?..........................................................
7. How long have you been in the TAC Cup program? ……… years

### Section B: Injury Information

8. Have you ever had any injuries that required you to stop playing football for more than 4 weeks (either training OR competition)? YES NO (please circle)
9. How many injuries? ………

   Describe each injury (body part, type of injury, time unable to play football/ length of recovery etc.):
   ........
   ................

10. Have you had surgery for any injuries? YES NO (please circle)

   For which injury/ies?..................................................................................................................

11. Have you been injured this year? YES NO (please circle)

   Indicate the location of the injury/ies:
   □ ankle/ shin / foot □ low back / neck □ knee
   □ shoulder □ hip / groin / thigh □ elbow / wrist / hand

12. Do you currently have any injuries? YES NO (please circle)

   Please describe:
   ..........................................................................................................................................
   ..........................................................................................................................................

Please return to the research person at your club who will collect this at your first assessment of training dairy/ injury log
Plain Language Statement

Date: 30/3/2009

Full Project Title: Measuring training loads and injury in TAC Cup football players

Principal Researcher: Associate Professor Jill Cook

Student Researcher: Mr Brendan Henderson

Associate Researcher(s): Dr Paul Gastin, Professor Caroline Finch, Dr Jason Berry

This Plain Language Statement and Consent Form is six pages long. Please make sure you have all the pages.

1. Your Consent

Your son is invited to take part in this research project. This Plain Language Statement contains detailed information about the research project. Its purpose is to explain to you as openly and clearly as possible all the procedures involved in this project so that you can make a fully informed decision whether your son is going to participate.

Please read this Plain Language Statement carefully. Feel free to ask questions about any information in the document. You may also wish to discuss the project with a relative or friend or your local health worker. Feel free to do this.

Once you understand what the project is about and if you agree for your son to take part in it, you will be asked to sign the Consent Form. By signing the Consent Form, you indicate that you understand the information and that you give your consent for your son to participate in the research project.

You will be given a copy of the Plain Language Statement and Consent Form to keep as a record.

2. Purpose and Background

The purpose of this project is to evaluate the validity of key measures of exposure and injury in junior Australian football players by examining different methods of data collection. The project will prospectively record training load and injury. This is a student project towards a Master of Science research degree. A total of 160 people will participate in this project.
There are currently no guidelines for training loads in junior football and there are few data that have documented training load and injury in young football players. This pilot study seeks to validate measures of training load and injury in young footballers from rural and urban demographical areas. This study aims to underpin proposed subsequent research that will follow athletes over the transition from junior to senior sport and investigate what strategies should be used in junior sport to maximise senior participation. This study focuses on Australian football because of its high participation rates and prevalence of injury. Junior Australian football players in the TAC Cup competition have been chosen as they are pre-elite athletes with a high exposure to training loads in football and across other sports.

*Your son has been invited to participate in this research project because he is currently playing and training in the TAC Cup competition. The results of this research may be used to help researcher Brendan Henderson to obtain a Master of Science degree.*

3. Funding

*This research is* totally funded* by the Deakin University /University of Ballarat collaboration fund.*

4. Procedures

Your son will undertake their normal football training and playing. He will be asked to wear a GPS unit for some of his training sessions. This is a small matchbox sized unit that is worn in a custom harness between the shoulder blades. This unit measures how far and fast he runs and his heart rate. This will not interfere with his capacity to train and is commonly used in elite senior football competitions without problems. There is no time commitment aside from putting on and taking off the GPS.

In addition, participation in this project will involve your son documenting his training hours, his injuries and how hard he thought training was. This will be done with the study’s research assistant at training. This will take about 10 minutes each week. The research assistant will report regularly to the researchers, and the progress of the study will be monitored regularly.

5. Possible Benefits

*Possible benefits from this study include the quantification of training loads in junior football players and if training loads are linked to injury. We cannot guarantee or promise that your son will receive any benefits from this project.*

6. Possible Risks

*We do not foresee any risks to your son by his participation in this study.*

7. Privacy, Confidentiality and Disclosure of Information
The data from this study will be stored at Deakin University in a locked filing cabinet and on password protected computers. After 6 years the data will be disposed. All data in this project will be de-identified. Only researchers in this study will have access to the data.

Any information obtained in connection with this project and that can identify your son will remain confidential. It will only be disclosed with your permission, subject to legal requirements. In any publication, information will be provided in such a way that your son cannot be identified.

8. Results of Project

Your son’s TAC Cup club will be provided with a report from this study and they will give you a copy if you request one.

9. Participation is Voluntary

Participation in any research project is voluntary. If you do not wish your son to take part you are not obliged to. If you decide to let your son take part and later change your mind, you are free to withdraw him from the project for the rest of the season. Any information obtained from you to date will not be used and will be destroyed.

Your decision whether to let your son take part or not to take part, or to take part and then withdraw, will not affect his football participation or his relationship with Deakin University and the University of Ballarat

Before you make your decision, a member of the research team will be available to answer any questions you have about the research project. You can ask for any information you want. Sign the Consent Form only after you have had a chance to ask your questions and have received satisfactory answers.

If you decide to withdraw your son from this project, please notify a member of the research team or complete and return the Revocation of Consent Form attached. This notice will allow the research team to inform you if there are any special requirements linked to withdrawing.

10. Ethical Guidelines

This project will be carried out according to the National Statement on Ethical Conduct in Human Research (2007) produced by the National Health and Medical Research Council of Australia. This statement has been developed to protect the interests of people who agree to participate in human research studies.

The ethics aspects of this research project have been approved by the Human Research Ethics Committee of Deakin University. The TAC Cup competition has given their approval for the research to be conducted.

11. Complaints
If you have any complaints about any aspect of the project, the way it is being conducted or any questions about your rights as a research participant, then you may contact:

The Executive Officer, Human Research Ethics Committee, Deakin University, 221 Burwood Highway, Burwood Victoria 3125, Telephone: 9251 7123, Facsimile: 9244 6581; research-ethics@deakin.edu.au. Please quote project number EC [number] -2008.

12. Reimbursement for your costs

Your son will not be paid for his participation in this project.

13. Further Information, Queries or Any Problems
If you require further information, wish to withdraw your son’s participation or if you have any problems concerning this project you can contact the principal or associate researchers. Should you have any concern about the conduct of this research project, please contact the Secretariat, Deakin University Human Ethics Advisory Group, Health, Medicine, Nursing and Behavioural Sciences. Phone: 03 9251 7175. Email: steven.sawyer@deakin.edu.au

The researchers responsible for this project are:

Associate Professor Jill Cook, Dr Paul Gastin, Mr Dawson Kidgell, Mr Brendan Henderson

School of Exercise and Nutrition Sciences,

Faculty of Health, Medicine, Nursing and Behavioural Sciences

Deakin University [Burwood] Australia
Phone: 03 9244 6040, 0410754549 (AH)
Email: jill.cook@deakin.edu.au

Professor Caroline Finch, Dr Jason Berry
University of Ballarat
**DEAKIN UNIVERSITY**

**PLAIN LANGUAGE STATEMENT AND CONSENT FORM**

**TO: Parents/Guardians**

---

### Third Party Consent Form

*(To be used by parents/guardians of minor children, or carers/guardians consenting on behalf of adult participants who do not have the capacity to give informed consent)*

**Date:**

Full Project Title: Measuring training loads and injury in TAC Cup football players

---

I have read, or have had read to me and I understand the attached Plain Language Statement.

I give my permission for …………………………………………………… (name of participant) to participate in this project according to the conditions in the Plain Language Statement.

I have been given a copy of Plain Language Statement and Consent Form to keep.

The researcher has agreed not to reveal my identity and personal details, including where information about this project is published, or presented in any public form.

**Participant’s Name (printed) .................................................................**

**Name of Person giving Consent (printed) ..................................................**

**Relationship to Participant: .................................................................**

**Signature ................................................................. Date ...........................**

---

Associate Professor Jill Cook

School of Exercise and Nutrition Sciences,

Faculty of Health, Medicine, Nursing and Behavioural Sciences

Deakin University [Burwood] Australia

Phone: 03 9244 6040, 0410754549 (AH)

Email: jill.cook@deakin.edu.au
DEAKIN UNIVERSITY
PLAIN LANGUAGE STATEMENT AND CONSENT FORM

TO: Parents/Guardians

Revocation of Consent Form

(To be used for participants who wish to withdraw from the project)

Date;

Full Project Title: Measuring training loads and injury in TAC Cup football players

I hereby wish to WITHDRAW my consent to participate in the above research project and understand that such withdrawal WILL NOT jeopardise my relationship with Deakin University and the University of Ballarat

Participant’s Name (printed) …………………………………………………….
Signature ……………………………………………………………………….
Date ……………………

Please mail or fax this form to:

Associate Professor Jill Cook

School of Exercise and Nutrition Sciences,
Faculty of Health, Medicine, Nursing and Behavioural Sciences
Deakin University [Burwood] Australia
Phone: 03 9244 6040, 0410754549 (AH)
Email: jill.cook@deakin.edu.au
Appendix 6  Training diary information brief

Dear participants,

Attached is the training diary that we would like you to fill out each day. We want you to document ANY time you play sport (football or not), including any training and competition, or recreational physical activity participation. For the most accurate record taking, you are requested to fill it in at the end of each physical activity/training session you undertake.

You need to enter the amount of time in minutes the session went for in the time column. You will be required to enter a Rating of Perceived Exertion (RPE) score. This is how physically hard you felt the session was on a 1-10 scale; with one representing a session that requires no exertion at all, and ten representing a maximal exertion session. The scale does not represent how tired you are after training, rather how physically demanding or intense you felt the actual training was.

On the training diary record form, briefly describe of the type of activity undertaken in the “Recreation Activities” row, e.g. kick to kick, swimming. We have attached an example of a completed form as a guide. You will be required to hand in these forms to the researchers each week at your training sessions at the club.

If you have any queries about this form, or the research project entitled “Quantification of training load in elite junior ARF players”, do not hesitate to contact the researchers:

We appreciate your involvement in this project.
Appendix 7  Rating of perceived exertion brief

RPE Brief:

The rating of perceived exertion is a scale that will allow us to monitor your training load in regards to the skill components and drills that you undertake at training. The scale below outlines what each number on a 1-10 scale represents in regards to how physically hard training was.

Please make note that that the score you give should not represent how tired or exhausted you are after training, rather how physically demanding or intense you felt the actual training was.

SCALE:

0    Rest
1    Very, Very Easy
2    Easy
3    Moderate
4    Somewhat Hard
5    Hard
6    -
7    Very Hard
8    -
9    -
10   Maximal

Reference: (Foster, Daines et al. 1996)
## Appendix 8 Weekly training diary log

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<th>Monday</th>
<th>Tuesday</th>
<th>Sunday</th>
<th>Weekly Total/Average</th>
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<td>Time</td>
<td>RPE</td>
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<td>Conditioning</td>
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<tr>
<td>School/Club Football</td>
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<tr>
<td>Daily Totals/Average</td>
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