The relationship between training load and incidence of injury and illness over a pre-season at an Australian Football League Club

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USE OF THESIS

ABSTRACT

In any competitive sporting environment, it is crucial to a team's success to have the maximum number of their players free from injury and illness and available for selection in as many games as possible throughout the season. The training programme of the club, and therefore training load, can have an impact on the incidence of injury and illness amongst the players. The purpose of this study was to investigate the relationship between the training load and the incidence of injury and illness over an entire pre-season at an Australian Football League (AFL) club. Sixteen players were subjects; all full time professional male AFL players (mean ± standard deviation; age 23.8 ± 5.1 years; height 188.9 ± 7.4 m; weight 90.9 ± 9.2 kg). A longitudinal research design was employed, where training load, injury and illness were monitored over a 15 week pre-season and Pearson Correlation Coefficients were used to examine relationships. Training load was measured in four different ways; Rating of Perceived Exertion (RPE) × time, mins > 80% max HR, total distance run and total distance run > 12 km/h. Strain and monotony were also determined. The study provided valuable insight into the training demands of an AFL club. There were few instances of injury (n = 5) and illness (n =12) over the pre-season. There was a significant relationship between total distance run and incidence of injury (r = -0.52, p = 0.048). It was found that 42% of illnesses could be explained by a preceding spike in training load, whilst 40% of injuries could be explained by a preceding spike in training load. The findings of this study show that accurately monitoring training load can help predict where illnesses and injuries may occur. More research is warranted on the monitoring of training load and its relationship with injury and illness in team sports.

DECLARATION

I certify that this thesis does not, to the best of my knowledge and belief:

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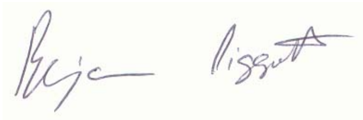

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CHAPTER ONE
INTRODUCTION

Australian Rules Football (ARF) is a fast moving sport played on a relatively large ground and places a high demand on fitness as well as technical, tactical and mental qualities (Young et al., 2005). Each club in the Australian Football League competition has 44 players on their playing list with 22 players being selected for the senior team (highest level) each weekend. At any point in time, there are 18 players on the ground and four players on the interchange bench with teams allowed to make unlimited interchanges throughout the game. Games are played over four 20 minute real time quarters (ball actually in play), including breaks at the end of each quarter. It is essential that the coaching staff has as many of their listed players as free from both injury and illness as possible and available for selection in the senior team if they are to be successful.

The preparation phase for each team begins with the pre-season which can last up to twenty weeks and include four pre-competition games. There are 22 rounds of competition amongst the 16 Australian Football League (AFL) Clubs, with the top eight teams progressing through to a finals series. Players require high levels of both skill and physical fitness if they are to compete at the highest level. Optimally developing each athlete both physically and technically in the team environment is a great challenge and one which requires high levels of planning and understanding by team coaches (Cormack, 2001).

ARF is a physically demanding sport that stresses the three energy systems. It is also felt that the game is becoming faster due to improved ground surfaces, contemporary training and playing methods, increased number of interchange players and technical resources (Buttifant, 2003). Young et al., (2005) published a case study of physiological and anthropometric characteristics (mean ± standard deviation) of players at an ARF club. Anthropometric characteristics showed that players that were classed as midfielders (generally play in midfield and follow the ball around the ground) had a stature of 1.88 ± 0.09 m, weight of 86.0 ± 8.9 kg and sum of 8 skinfolds of 47.0 ± 7.8 mm. Young et al., (2005) reported that the midfielders had a 10m sprint time of 1.90 ± 0.06 s, flying 30m time of 3.48 ± 0.11 s, a vertical jump of 62.3 ± 3.7 cm and a predicted VO2 max of 61.6 ± 3.5 ml.kg-1.min-1.

The importance of players possessing high skill and fitness levels has resulted in AFL club's implementing demanding training loads at the elite level. In previous years, a single training session per day was considered to be sufficient, whereas today, athletes regularly train twice a day (Kentta & Hassmen, 1998). Coaches are under increasing pressure to achieve success therefore the boundaries are continually being tested with regard to what the players can achieve and what their bodies can withstand. Training for success has increasingly become a balance between achieving peak performance and avoiding the negative consequences of overtraining (Kentta & Hassmen, 1998). Training volumes below what can be considered optimal do not result in the desired adaptation whereas training volumes above the optimum may lead to a condition usually referred to as the 'overtraining syndrome', 'staleness' or 'burnout' (Kentta & Hassmen, 1998). Training for collision sports (which includes AFL) reflects a balance between the minimum training load required to elicit an improvement in fitness and the maximum training load tolerable before sustaining marked increases in injury rates (Gabbett and Domrow 2007). It relies on the art of coaching to provide the optimal amount of training without exceeding an individual's exercise tolerance and recovery capacity (Bruin, Kuipers, Keizer, & Vander Vusse, 1994).

In addition, the recovery process is also vitally important due to the demanding nature of training, games and travel. Achieving an appropriate balance between training sessions, competition stresses and recovery is important in maximising the performance of athletes (Barnett, 2006). Lack of appropriate recovery in pre-season may result in the athlete being unable to train at the required intensity or complete the required load at the next session, thereby predisposing the athlete to injury (Barnett, 2006).

Hence, there is a need to monitor the training patterns of AFL players to enable the correct training loads to be implemented and allow the training load and recovery ratio to provide positive training adaptations. The use of such practices allows negative adaptations to training to be minimised and appropriate fitness and skill levels achieved such that players are able to perform at their highest level. Various methods have been used to monitor training load in team sports including the use of heart rate (Coutts, Rampinini, Marcora, Castagna, & Impellizzeri, 2007; Esposito et al., 2004; Hoff, Wisloff, Engen, Kemi, & Helgerud, 2002; Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004; Impellizzeri, Rampinini, & Marcora, 2005; Stagno, Thatcher, & van

Someren, 2007; Tessitore, Meeusen, Piacentini, Demarie, & Capranica, 2006). Another method employed to monitor training is the use of a rating of perceived exertion (RPE) scale where subjects are required to rate the difficulty of training at the end of each session (Cormack, 2001). A further method of monitoring training involves the calculation of training load (RPE of session × session time), which has been used extensively in previous research (Anderson, Triplett-McBride, Foster, Doberstein, & Brice, 2003; Coutts, Wallace, & Slattery, 2004; Foster et al., 2001; Kelly & Coutts, 2007; Putlur et al., 2004).

Studies have been completed that monitor training load in various sports and explore the relationship between training load, injury and illness (Anderson, Triplett-McBride, Foster, Doberstein, & Brice, 2003; Gabbett, 2004a; Gabbett, 2004b; Putlur et al., 2004). Anderson, Triplett-McBride, Foster, Doberstein, & Brice (2003) monitored training load and the incidence of injury and illness in a women's NCAA Division III Basketball team and found that there was an increase in injuries when the training load increased, whilst there was no correlation between training loads and illness. Gabbett (2004a) reported that in rugby league, as the intensity, load and duration of the training sessions and games increased, so too, did the incidence of injury. Putlur et al. (2004) observed that 53-64% of the illnesses that occurred in University level soccer players were associated with a proceeding spike in training load, monotony or strain.

1.1 Purpose of Research

The purpose of this study was to investigate the relationship between training load and the incidence of injury and illness in a group of AFL players.

1.2 Hypothesis

The hypothesis was that training load does affect the incidence of injury and illness at an AFL club. It was hypothesized that the higher the training loads (as measured by total training load, time spent above 80% maximum heart rate, kilometres run and kilometres run >12km/hr), monotony and strain, the greater the incidence of both injury and illness.

1.3 <u>Significance of Research</u>

This study is considered valuable for coaching and support staff of AFL teams as it provides information on:

(1) ***Total training load of an AFL club over pre-season***

Studies have been completed that focus on monitoring of training load in other sports including basketball, soccer and rugby league (Anderson, Triplett-McBride, Foster, Doberstein, & Brice, 2003; Gabbett, 2004a; Gabbett, 2004b; Impellizzeri, Rampinini, Coutts, Sassi & Marcora 2004; Putlur et al., 2004), however to date there is a dearth of such information examining AFL.

(2) ***Training load and incidence of injury***

There have been no published studies that examine the relationship between training load and the incidence of injury in AFL at national or club level. Gabbett (2004a; 2004b) has researched the influence of training and match intensities in amateur and semi professional rugby league, yet there have been no such studies completed in AFL.

(3) ***Training load and incidence of illness***

This study is significant as there have been no published studies that examine the relationship between training load and the incidence of illness at an AFL Club. Studies of this nature have been completed in both basketball and soccer (Anderson, Triplett-McBride, Foster, Doberstein, & Brice, 2003; Putlur et al., 2004), yet no studies have examined the relationship between training load and illness at an AFL Club.

(4) ***Training load at an AFL club as defined by time spent above 80% maximum heart rate, kilometres run and kilometres run >12km/h***

There have been no published studies that have measured training load in AFL in terms of heart rate (time spent above 80% maximum heart rate). Numerous studies have been completed involving the use of heart rate in training and activities in other team sports such as soccer (Esposito et al., 2004; Hoff, Wisloff, Engen, Kemi, &

Helgerud, 2002; Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004; Impellizzeri, Rampinini, & Marcora, 2005; Tessitore, Meeusen, Piacentini, Demarie, & Capranica, 2006), however they are non-existent in AFL. Kilometres run was measured using Global Positioning Systems (GPS) and there have been some studies that use GPS systems in the area of sport (Dobson & Keogh, 2007; Edgecomb & Norton, 2006; Larrson & Henriksson-Larsen, 2001; Larsson, 2003; Wisbey & Montgomery, 2006) and horse racing (Hebenbrock et al., 2005). There is limited research using GPS to monitor training load in sport in general, in particular AFL.

1.4 <u>Research Questions</u>

- What is the relationship between training load and the incidence of injury and illness in AFL players?
- What is the training load of an AFL player over pre-season in terms of total training load (RPE × time), heart rate (minutes above 80% maximum heart rate) and kilometres run, and in particular the amount of high intensity running (> 12 km/h)?
- What is the relationship between training monotony and strain and incidence of injury and illness in AFL players?

CHAPTER TWO
LITERATURE REVIEW

2.1 Monitoring Training Load

The ultimate goal of training is to prepare athletes to perform at their best in important competitions (Suzuki, Sato, Maeda, & Takahashi, 2006). The ability to monitor training is critical to the process of quantifying training periodization plans (Foster et al., 2001). By monitoring training accurately and effectively, athletes will receive the desired training effect and be prepared for competition, whilst minimizing injury and illness. Injury and/or illness can occur when physical demands outweigh the body's ability to fully recover between training sessions and competitions (Anderson, Triplett-McBride, Foster, Doberstein, & Brice, 2003). Coaches and athletes both stand to benefit from accurate training load monitoring (Coutts, Wallace, & Slattery, 2004).

2.2 Borg's RPE Scale

The Borg RPE scale (Borg, 1998) is a simple, yet very effective method of monitoring exercise. The RPE scale was developed to enable reliable and valid estimations of perceived exertion and is now commonly used in exercise testing, training, and rehabilitation (Borg, 1998). Borg's RPE scale (Borg, 1998) was centred around the idea that a measure of perceived exertion is the level of strain and /or heaviness that is experienced during physical effort. The given definition of RPE refers to overall perceived exertion, which depends on many factors including sensory cues and somatic symptoms, emotional factors and rating behaviour (Borg, 1998). The original scale has been modified and the CR (Category Ratio) 0-10 RPE scale has become a standard method to evaluate perceived exertion in exercise testing, training and rehabilitation (Day, McGuigan, Brice, & Foster, 2004). An example of an RPE chart is shown in Figure 1.

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

Figure1. Modified Rating of Perceived Exertion (RPE) Scale (Foster et al., 2001)

The sessional RPE is the athlete's rating of the global intensity of the exercise bout (Foster et al., 2001). The goal of session RPE is to encourage the athlete to view the session globally and to simplify the myriad of exercise intensity cues during the exercise bout (McGuigan & Foster, 2004). This allows researchers or the coach to evaluate trends in training, injury, and illness in relation to the session RPE (McGuigan & Foster, 2004). The effective use of session RPE could also lead to optimal athletic performance with a reduced injury/illness cost from overtraining, due to a greater training synchrony between a coach-designed training regimen and the actual intensity at which athletes train (Sweet, Foster, McGuigan, & Brice, 2004). Coutts (2001) suggested that the major advantage of the session RPE method of monitoring training is that it is simple and easy to implement. It is also easy for athletes to understand and is less invasive than other methods (Coutts, 2001).

2.3 Training Load and Team Sports

The fundamental goal for a coach is to optimise athletic performance (Coutts, 2001). The greatest performance gains come from prescribing an optimal amount of physical training with appropriate recovery periods to allow for the greatest adaptation before competition (Coutts, 2001). Coutts (2001) suggested that prescribing the correct training loads for team sport players is a difficult task, as planning loads for skill, endurance, strength, speed agility, and flexibility development are required for many athletes of different physical and skill capabilities. Designing a suitably stringent training programme requires an appreciation of the need for implementing, analysing, assessing, and modifying training regimens based on the specific requirements of the sport under consideration (Suzuki, Sato, Maeda, & Takahashi, 2006). Team sport athletes often complete a large volume of high intensity training during the pre-season preparation period so that these physical capacities can be optimized prior to the competition season (Coutts, Reaburn, Piva, & Murphy, 2007). The most value a coach can get from accurately monitoring training load is a better understanding of each individual's tolerance to training (Coutts, Wallace, & Slattery, 2004).

In a team sport such as AFL, much of the training and conditioning is done in groups and this has very important implications for the training load on individuals within that group. Impellizzeri, Rampinini & Marcora (2005) investigated the physiological assessment of aerobic training in the team sport of soccer, and stressed that coaches need to be extremely aware of an individual's internal training load (physiological responses) that results from an external training load being applied. The physiological stress (internal load) induced by group training (i.e. same external training load) often differs between individuals (Impellizzeri, Rampinini, & Marcora, 2005). Impellizzeri, Rampinini & Marcora (2005) found that the session RPE could be an important tool for coaches at all levels, and specifically, that this simple method has the potential to become a key tool for coaches and sport scientists to monitor internal training load.

Further supporting evidence of the use of session RPE scale in team sports resulted from the work of Impellizzeri, Rampinini, Coutts, Sassi, & Marcora (2004). Their research involved using Foster's RPE based method (multiplying training time by session RPE score) (Foster et al., 2001), to provide an internal training load which was then correlated with various methods used to determine internal training load based on heart rate responses to exercise. Impellizzeri, Rampinini, Coutts, Sassi, & Marcora (2005) concluded that the session RPE method can be considered a good indicator of global internal load of soccer training and can be very useful and practical for coaches to monitor and control internal load. As RPE represents the athlete's own perception of training stress, which can include both physical and psychological stress, the session-RPE method may provide a valuable measure of internal training load (Impellizzeri, Rampinini, & Marcora, 2005). In addition, Impellizzeri, Rampinini, Coutts, Sassi, &

Marcora (2005) suggested that the RPE-based method may assist in the development of specific periodisation strategies for individuals and teams.

Little and Williams (2007) researched the effectiveness of using heart rate and Borg's RPE scales to monitor five soccer training drills completed by 28 professional players. The results showed that the RPE scale appears to be a valid marker of exercise intensity for all the soccer drills tested (Little & Williams, 2007). Kelly and Coutts (2007) suggested a model that can be used to guide in-season training loads in team sports using Foster's (2001) RPE based method. The RPE model is a simple system for strength and conditioning coaches to monitor load of several different modalities of training including technical, tactical, endurance, speed and strength (Kelly & Coutts, 2007). Kelly and Coutts (2007) also suggested that the simplicity of the system makes it effective for quantifying training load for team sports.

The session RPE method of monitoring training stress is suitable for monitoring team sports as it enables the coach to accurately combine training loads from different training modalities to give an accurate estimation of overall training load (Coutts, 2001). By monitoring team sport training effectively, a greater understanding of optimal training will be developed, ultimately delivering peak competitive performance on the field (Coutts, 2001).

In a study by Cormack (2001) the team average RPE was recorded for each session completed and this reflected very closely, heart rate data collected during each session. Perceived exertion ratings also appeared to be linked to the number of players who missed sessions due to muscle soreness or injury (ie. a succession of high RPE values was inevitably followed by higher number of players missing sessions) (Cormack, 2001).

2.4 <u>Session RPE and Differing Exercise Intensities</u>

Studies have examined the use of RPE with exercise of differing intensities (Dunbar et al., 1992; Foster et al., 2001; Glass, Knowlton, & Becque, 1992; Noble, Borg, Jacobs, Ceci, & Kaiser, 1983). Dunbar et al., (1992) examined the regulation of exercise intensity by using RPE. The RPE equivalent to 50% and 70% VO2 max was estimated using standard clinical protocols and a treadmill and cycle ergometer. Subjects then produced target RPE's employing these modalities. Dunbar et al., (1992) concluded that RPE provides a physiologically valid method of regulating exercise intensity. Noble, Borg, Jacobs, Ceci, & Kaiser (1983) investigated the relationship between perceptual ratings from Borg's scale and selected physiological variables during exercise. The research showed that the scale ratings were closely related to blood and muscle lactate accumulation. They concluded that ratings from the category-ratio scale correspond very well with glycogenolytic metabolism leading to lactate accumulation during exercise.

Glass, Knowlton, & Becque (1992) concluded from their research involving a graded exercise test (GXT) that an RPE obtained from a GXT can accurately serve as a method of prescribing exercise intensity during level treadmill running. Foster et al. (2001) showed that the session RPE concept provides a valid method of quantifying exercise training independent of technologically intensive methods of recording exercise training intensity. Care needs to be taken when comparing studies that use RPE vs session RPE as these are different perceptual measures and should be interpreted with caution when comparisons are made.

2.5 Session RPE and Resistance Training

Resistance training plays a key role in conditioning athletes for the specific strength and conditioning demands of different sports (Egan, Winchester, Foster, & McGuigan, 2006). In recent years, research using the Borg's RPE scale (Borg, 1998) found that it is an accurate and effective method of monitoring resistance training (Day, McGuigan, Brice, & Foster, 2004; McGuigan & Foster, 2004; Singh, Foster, Tod, & McGuigan, 2007; Sweet, Foster, McGuigan, & Brice, 2004). Resistance training is a complex model of exercise where several factors, such as the number of sets and repetitions, the amount of rest and the type of exercise, will all affect the perceptual signal (McGuigan & Foster, 2004). McGuigan & Foster (2004) suggested that the session RPE method can not only be considered a valid technique to prescribe work intensities and provide for progressive increases in resistance, but that the session RPE scale would be of great significance to those involved in resistance training.

Further support for the use of session RPE in resistance training resulted from the work of Day, McGuigan, Brice, & Foster (2004) who investigated the reliability of the session RPE scale to quantify exercise intensity during high, moderate and low intensity resistance training. Their work found that performing fewer repetitions at a higher intensity was perceived to be more difficult than performing more repetitions at a lower intensity. The authors concluded that the session RPE was a reliable method to quantify various intensities of resistance training.

Sweet, Foster, McGuigan, & Brice (2004) examined whether the session RPE method, could be used with resistance training. Subjects performed 3 × 30 minute aerobic trials on a cycle ergometer at increasing intensities rating the global intensity of each trial using RPE scale. Subjects also performed 3 × 30 minute resistance exercise bouts with a varying number of sets and intensities, also rating the global intensity of each session using the RPE scale. They concluded that session RPE appears to be a reasonable method (due to high correlation with RPE) for quantifying the intensity of resistance training and concluded that coaches and athletes can use the session RPE method to quantify resistance and aerobic training.

Singh, Foster, Tod, & McGuigan (2007) evaluated the effectiveness of session RPE to measure different types of resistance training. Subjects performed 5 exercises with different intensities, rest periods and number of repetitions. Their research complemented previous studies reporting that use of the session RPE method after each testing session would allow coaches to assess the intensity levels that correspond to the level of the training programme. Singh, Foster, Tod, & McGuigan (2007) concluded that the session RPE method appears to be effective in monitoring different types of resistance training.

2.6 Training Load and Injury

Specific studies have monitored training load and explored the relationship between this indice and injury in different sports (Anderson, Triplett-McBride, Foster, Doberstein, & Brice, 2003; Gabbett, 2004a, 2004b; Putlur et al., 2004). Anderson, Triplett-McBride, Foster, Doberstein, & Brice (2003) monitored training load and the incidence of injury and illness in a women's NCAA Division III Basketball team and found that there was a strong link between training load and injury; there was an increase in injuries when the training load increased. The results of this study need to be interpreted with some caution though as the sample size was relatively low (n=12) which influenced the statistical power of the study. The highest incidence of injuries in this study occurred in the third and twelfth weeks of training which coincided with when the training load was highest. Typically, the first two weeks of a season are frequently the most difficult and physically demanding sessions of the season (Anderson, Triplett-McBride, Foster, Doberstein, & Brice, 2003). In the same study it was found that there was no correlation between training loads and illness.

Gabbett (2004a) examined the relationship between intensity, duration and load of training and matches and the incidence of injury in semi-professional rugby league players. In this study, the highest incidence of injuries (205.6 per 1000 training hours) was recorded in February (end of pre-season), when the training load was the highest. This study also found that more training injuries occurred in the first half of the season as compared to the second (69.2% vs 30.8%). Gabbett (2004a) reported that the incidence of training injuries was highly correlated with the intensity, duration and load of training despite the implementation of a game specific, periodized training programme.

A recent study by Gabbett and Domrow (2007) explored the relationships between training load, injury and fitness in sub-elite collision sport athletes (rugby league). One conclusion of this study was that with an increased training load, particularly during the pre-season training phase, there is an increase risk of injury in collision sport athletes. Gabbett and Domrow (2007) expanded on this by stating that the high incidence of overuse, overexertion, and lower-limb injuries in the pre-season training phase lends support to the finding that in collision sport athletes, increases in injury risk during the pre-season training period are closely related to increases in training load.

In 1992, the AFL implemented an injury surveillance system for the elite level called the AFL Injury Survey. Figures released recently suggest that injury rates at the elite level are at an historical low (Gabbe, Finch, & Cameron, 2007). Each year the Australian Football League publishes the results from this survey in a report that examines the incidence of injuries in the 16 AFL clubs and attempts to identify any developing trends with regard to injury. The AFL Injury Report: Season 2005 (Orchard & Seward, 2006) reported that for that particular season it was a low year for injuries compared to the long-term average with hamstring injuries, knee anterior cruciate ligament injuries and groin injuries (including osteitis pubis) consistently the most prevalent injuries. Hamstring strains have been the most common injury in every year of the survey, with generally six of these injuries occurring per club per season (Orchard & Seward, 2006). Orchard & Seward (2006) also acknowledge that improved management and injury prevention activities at club level are possibly positively affecting the relatively low incidence of injuries as a whole. This information is very valuable and insightful with regard to injury types and incidence. Club physiotherapists and strength and conditioning coaches can see how their club sits in relation to the overall incidence and trends of injuries in the AFL. However, this report does not examine the relationship between training loads and the incidence of injury or illness.

2.7 Training Load and Illness

"Sports immunology" involves examining the interaction of physical, psychological and environmental stress on the immune system (Pyne & Gleeson, 1998). There has been extensive research completed in this area with differing conclusions being reached (Mackinnon, 1997; Putlur et al., 2004; Pyne & Gleeson, 1998; Shephard & Shek, 1994). Mackinnon (1997) indicated that there is a general perception among athletes, coaches and sports physicians that athletes are susceptible to infectious illness during intensive training and major competitions. Shepherd & Shek (1993) have shown that moderate exercise may stimulate the immune system but hard training actually suppresses it, thus increasing the risk of infection. This could be particularly relevant for AFL players in both the pre-season when training loads are high, as well as during the in-season when competition games are being played and physical demands on the body are at a peak.

Shephard and Shek (1994) suggested that moderate endurance exercise causes no change or enhancement of immunity indices. However, exhausting exercise tends to produce adverse changes in these same indices, particularly if the physical activity is accompanied by environmental or competitive stress. It has been suggested that if athletic preparation is pursued to the level of staleness and/or muscle damage, then it can have substantial negative implications for many aspects of immune function (Shephard & Shek, 1994). Pyne and Gleeson (1998) reviewed a number of studies that had been completed in this area. The studies support the hypothesis that moderate exercise is beneficial to the immune system, whereas intensive exercise elicits a short term suppression in neutrophil oxidative activity which can lead to illness.

Putlur et al. (2004) examined the alteration of immune function in women collegiate soccer players (n=14) over a nine week competitive season and compared these results with a control group of college students. They reported that illness occurred at a higher rate among the soccer players although the incidence of illness amongst this group was at its lowest in weeks 7, 8 and 9 when the training load was reduced. Putlur et al. (2004) showed that 55% of the soccer player's illnesses could be explained by a preceding spike in training load and 82% of illnesses could be explained by a preceding decrease in salivary immunoglobin (S-IgA) levels. Whilst no actual training load values were reported in the research of Putlur et al. (2004), the strain values calculated are similar to that of previous research of high level athletes (Coutts, 2001). Foster (1998) showed that with experienced athletes, 84% of illnesses could be explained by a preceding spike in training load. This literature is supportive of the hypothesis that an increase in training load could lead to an increase in illness amongst athletes. There has been no research that investigates the relationship between training load and incidence of illness in AFL.

2.8 Use of GPS to Monitor Training

In competitive sport, it is beneficial for coaches and strength and conditioning coaches to have a comprehensive knowledge of specific player movements and patterns. In previous years these have been performed in AFL games and training using lapsed-time video analysis (Dawson, Hopkinson, Appleby, Stewart, & Roberts, 2004a, 2004b). The findings of this research concluded that total distance for midfielders to be ~17km, full forwards and fullbacks 13.6km, and half forwards and half backs covered 16km. Backs and forwards completed the highest number of sprints per game averaging around 30, whilst midfielders totalled 208 high intensity movements during a game (Dawson, Hopkinson, Appleby, Stewart, & Roberts, 2004a, 2004b).

GPS analysis is a relatively recent addition to sports science and there is limited published research in this area (Dobson & Keogh, 2007; Edgecomb & Norton, 2006; Larrson & Henriksson-Larsen, 2001; Larsson, 2003). Edgecomb & Norton (2006) suggest that one of the reasons for this limited research in regard to tracking in AFL, is that it is a collision sport where very few players wear protective padding or other equipment which limits the use of tracking that can be worn safely. In recent years, units have been made smaller and can be worn safely by players in games. With the production of sport-specific GPS hardware and software, the use of GPS as a training tool has increased in recent years (Dobson & Keogh, 2007). GPS allows the accurate tracking of a change in position (displacement) of an object (an athlete) in real time by calculating the displacement between the signal and the receiver (Dobson & Keogh, 2007).

Edgecomb and Norton (2006) found that the levels of error are relatively small when using GPS systems to monitor distance and that these systems could be used to track player movements in both games and conditioning sessions. The athlete can be provided with information such as distances covered, velocities achieved as well as frequency and duration of any sprints performed (Dobson & Keogh, 2007). Larsson (2003) indicated that the use of GPS for studying sport performance and training regimens, could enable a controlled monitoring of athletes. In combination with use of heart rate monitors, Larsson (2003) suggests that not only can speed in different sections of a training session be measured, but also the physiological response, which would allow an easy comparison between different sessions and athletes. Hebenbrock et al. (2005) evaluated the effectiveness of using GPS systems in monitoring the training and performances of horses, concluding that the system is suitable and reliable for the simultaneous recording of distance and velocity.

2.9 Use of Heart Rate to Monitor Training

Heart rate has been used extensively in research involving team sport activities as a means of measuring intensity (Coutts, Rampinini, Marcora, Castagna, & Impellizzeri, 2007; Esposito et al., 2004; Gamble, 2004; Hoff, Wisloff, Engen, Kemi, & Helgerud, 2002; Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004; Impellizzeri, Rampinini, & Marcora, 2005; Lamberts, Lemmink, Durandt, & Lambert, 2004; Little &

Williams, 2007; Stagno, Thatcher, & van Someren, 2007; Tessitore, Meeusen, Piacentini, Demarie, & Capranica, 2006). Impellizzeri, Rampinini, Coutts, Sassi, & Marcora (2004) found that heart rate monitoring is suitable for quantifying exercise intensity during most exercise sessions due to the close relationship between heart rate and maximal oxygen uptake (VO2 max).

Much of the team sport research involving heart rate recording has been in soccer (Esposito et al., 2004; Hoff, Wisloff, Engen, Kemi, & Helgerud, 2002; Little & Williams, 2007). Esposito et al. (2004) reported that, with the aid of laboratory reference tests, the physiological demands of soccer activities can be correctly estimated from HR measured on the field in amateur players. Hoff, Wisloff, Engen, Kemi, & Helgerud (2002) showed that heart rate monitoring during soccer specific exercise is a valid indicator of actual exercise intensity. Little and Williams (2007) measured exercise intensity using heart rate during drills involving 28 professional soccer players. They concluded that heart rate monitoring is probably the most advantageous method of monitoring exercise intensity, although it appears to underestimate intensity in drills that have shorter duration and induce fatigue rapidly.

Gamble's (2004) study evaluated changes in endurance fitness with 35 elite level rugby union players, involved in skill-based conditioning games during a nine week period over pre-season. In this study metabolic conditioning was conducted exclusively in the form of skill-based conditioning games in conjunction with HR telemetry. The results suggested that heart rate monitoring was an effective and practical means of quantifying intensity.

2.10 Use of Monotony and Strain in Monitoring Training

"Monotony" is a measure of the variability over training sessions and can be calculated by dividing the weekly training load by the standard deviation of that load for the week (Foster, 1998). "Strain" is the product of the weekly training load and monotony (Foster, 1998). The calculation of training monotony and strain and their relationships to both injury and illness have been the focus of previous research (Anderson, Triplett-McBride, Foster, Doberstein, & Brice, 2003; Foster, 1998; Lurken, Foster, McGuigan, Brooks, & Wright, 2005; Putlur et al., 2004).

This research has shown that as long as heavy exhaustive training is alternated with lighter training sessions, negative consequences such as overtraining are less likely to occur (Bruin, Kuipers, Keizer, & Vander Vusse, 1994). Foster (1998) demonstrated that high training load and high training monotony are both factors that relate to negative adaptations to training. He recommended that “easy” days be programmed within each week to allow a given training load to be accomplished with comparatively fewer negative outcomes. Anderson, Triplett-McBride, Foster, Doberstein, & Brice (2003) were unable to detect any overtraining symptoms in subjects from their study and suggested that one of the possible reasons for this was that high levels of monotony did not exist during the basketball season due to variability in how hard the practices were over the season. Putlur et al., (2004) concluded in their research that there appeared to be a relationship between training indices such as strain and monotony with the incidence of illness.

The literature review has shown that there is a real need to monitor training load of team sport athletes as it has been shown that there is a relationship between training load and injury and illness. RPE has been demonstrated to be a valid method of quantifying exercise across a variety of different exercise and exercise intensities. Heart rate has also been shown to be a valid measure of training load and has been employed extensively in monitoring of team sport. GPS is a relatively new tool for sport scientists with limited published research, yet it has been shown to be accurate for tracking player distance and speed. In addition, the training indices of monotony and strain have been shown to be valid and useful tools for also monitoring training.

CHAPTER THREE
METHODS

3.1 Experimental Design

A longitudinal research design was used with data gathered from the commencement of pre-season training 2007 and concluding at the completion of the pre-season competition matches. There were 15 training weeks in total. The pre-season training included team skills session, resistance training and general conditioning and sessions.

3.2 Subject Characteristics

Sixteen players were subjects for the study (mean ± standard deviation; age 23.8 ± 5.1 years; stature 188.9 ± 7.4 m; weight 90.9 ± 9.2 kg). All subjects were full-time professional Australian Football League players with the average "AFL age" (number of years on an AFL list as a full time professional AFL player) of 5.2 ± 2.6 years.

3.3 Training Program

Subjects participated in the planned pre-season training programme in preparation for the 2007 AFL season. This programme included activities that were designed to increase the physical fitness components and skill levels of all players. The training programme included sessions involving team skills, running, speed sessions, weight training and general conditioning. A typical week's training schedule is outlined in Table 1. There were individual differences in programme design for each player depending on what was considered the individual's greatest priority in terms of physical and skill development. This was determined by the coaching and the strength and conditioning staff

Table 1.

Typical Weekly Schedule

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Morning	Skills	Running and speed session	Skills	Conditioning	Skills	Running and speed session	Off
Afternoon	Weights	Recovery	Weights	Session	Weights	Recovery	Off

3.4 RPE Monitoring

Using the club's training database, subjects provided a sessional RPE (see Figure 1) rating the training session (including pre-season games) using the scale from zero (rest) to ten (maximal exertion). Subjects were asked approximately 30 minutes after the training session, "How was your workout?". Subjects were familiarised with the RPE scale before the commencement of the first session.

This information was recorded for each training session that the subjects completed, including all team skills, conditioning and resistance training sessions. From the information subjects provided using the club's training database, the following was calculated (Foster et al., 2001):

Training Load = Session RPE × Time
Monotony = Mean Weekly Training Load / Standard Deviation of Training Load
Strain = Monotony × Weekly Training

3.5 Monitoring Training Load with GPS Systems

In team skills sessions and conditioning sessions involving running, as well as pre-season games pre-season games, five 1Hz GPS systems (SPI Elite Sports Performance Indicator, Canberra) were used per session to record total distance run in kilometres and distance run above 12km/h. Players were randomly selected to wear GPS units and the data was collated and then averaged so that for each session, an average of the five GPS readings was recorded for both total distance and distance above 12km/hr.

3.6 Monitoring Training Load with Heart Rate Monitors

In team skills sessions, pre-season games and conditioning sessions 15 heart rate monitors (The Polar Team System, Finland) were used to record the subjects' heart rates. Each subject had a maximum heart rate recorded calculated from previous fitness testing (Multistage Fitness Test – mean score 14.4 ± 0.7). From this information, time spent in minutes above 80% of maximal heart rate was calculated for each subject and then averaged for the session. This information was calculated by one of the strength and conditioning staff of the club and recorded on the club's database.

3.7 Definition of Injury

Injury was defined as any pain or disability suffered by a player during a training session or game that restricted full participation in the general training programme. The injury was diagnosed by the club's physiotherapist and was then recorded by the club's strength and conditioning staff.

3.8 Definition of Illness

Illness was defined as occurrence where the player missed a training session or game due to a medical condition that was diagnosed by the club's doctor (eg influenza, gastroenteritis) which was then recorded by the club's strength and conditioning staff.

3.9 Statistical Analysis

Pearson Product Moment correlations were calculated to determine the relationship between training loads, monotony, strain and the incidence of injury and illness. Cohen's effect size (ES) statistics were calculated and interpreted using the following descriptors: > 0.7, large; 0.3-0.69 moderate; < 0.3 small (Cohen, 1988). The correspondence between spikes (>10% change) in the indices of training load, monotony and strain, and subsequent (within seven days) illness was noted (Foster, 1998) with a view to explaining the percentage of illnesses that could be explained by each index of training. One way repeated measures analysis of variances (ANOVA) were used to examine differences within training load, mins > 80 % max heart rate, monotony and strain. A level of significance of $p \leq 0.05$ was chosen prior to any statistical analysis.

When analysing data, the individual data from each player was recorded and then the average was taken for the values of training load, heart rate, monotony and strain. With regard to data for distance run and distance run > 12km/hr, the average data of the five players wearing GPS was used for the analysis. The reason for this is that only five GPS units were able to be used to record data and therefore not all players were able to wear a unit for every session; hence average sessional data was used. The fact that only five GPS units were used in sessions was a limitation of this study.

CHAPTER FOUR
RESULTS

The incidence of injuries and illnesses recorded over the fifteen week pre-season period are shown in Table 2. A total of five injuries were recorded for the pre-season period, with two of these occurring in week five. There were 12 incidences of illness over the pre-season period, with the majority of these (13 out of 14) occurring in the first half of the pre-season. The highest occurrence of illness was in week three with six athletes recording illnesses.

Table 2.

Incidence of Injury and Illness Over the 15 Week Pre-season

Week	Incidence of injury	Incidence of illness
1	0	0
2	1	2
3	0	6
4	0	1
5	2	1
6	0	0
7	0	1
8	0	0
9	1	0
10	0	0
11	0	0
12	0	0
13	0	0
14	1	0
15	0	1
TOTAL	5	12

There were no significant relationships between training load and injury or training load and illness in the pre-season period (Figure 2 and 3). The average weekly training load over the pre-season was 2945 ± 922 units. Peaks in the training load occurred in weeks 6 (4499 units) and 8 (4545 units) with the lowest training load occurring in week 10 coinciding with a value of 1612 units. A one-way repeated measures ANOVA revealed that there was a significant difference in training load from the peaks in weeks 6 and 8 and the nadir of week 10 ($p < .001$). Following the peak in week 8 of the pre-season, there was a general downward trend in training load to week 11 when the pre-season games commenced.

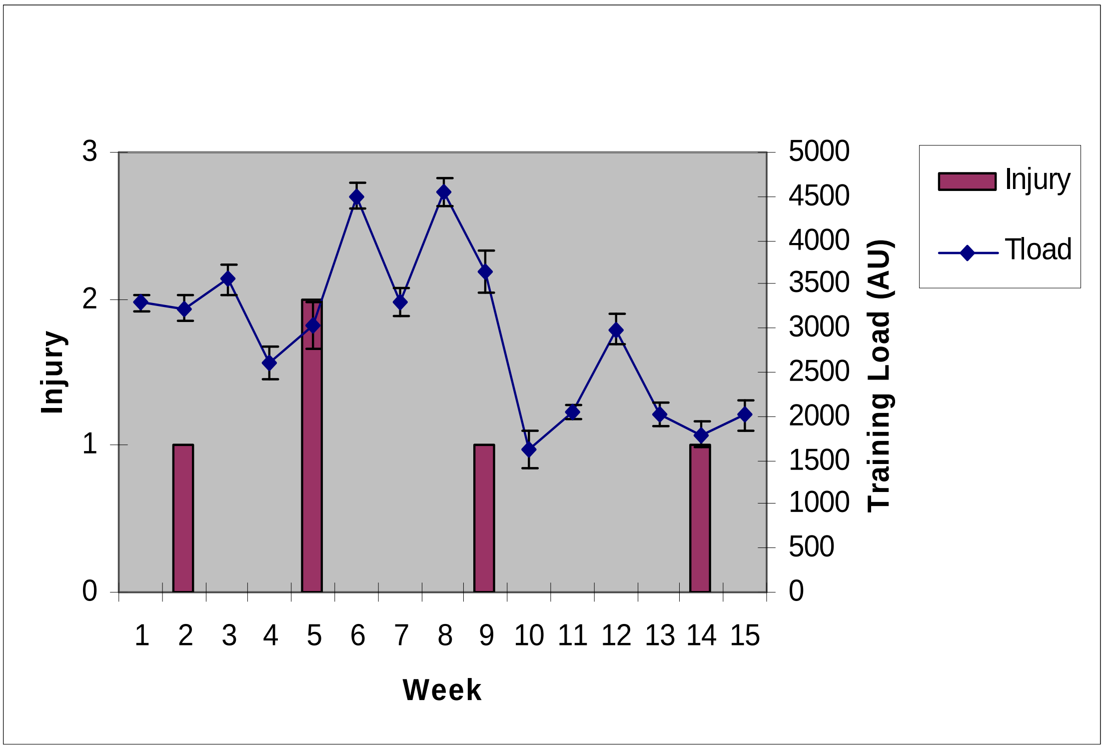

Figure 2. Training load (mean ± SEM) and incidence of injury over the 15 week pre-season

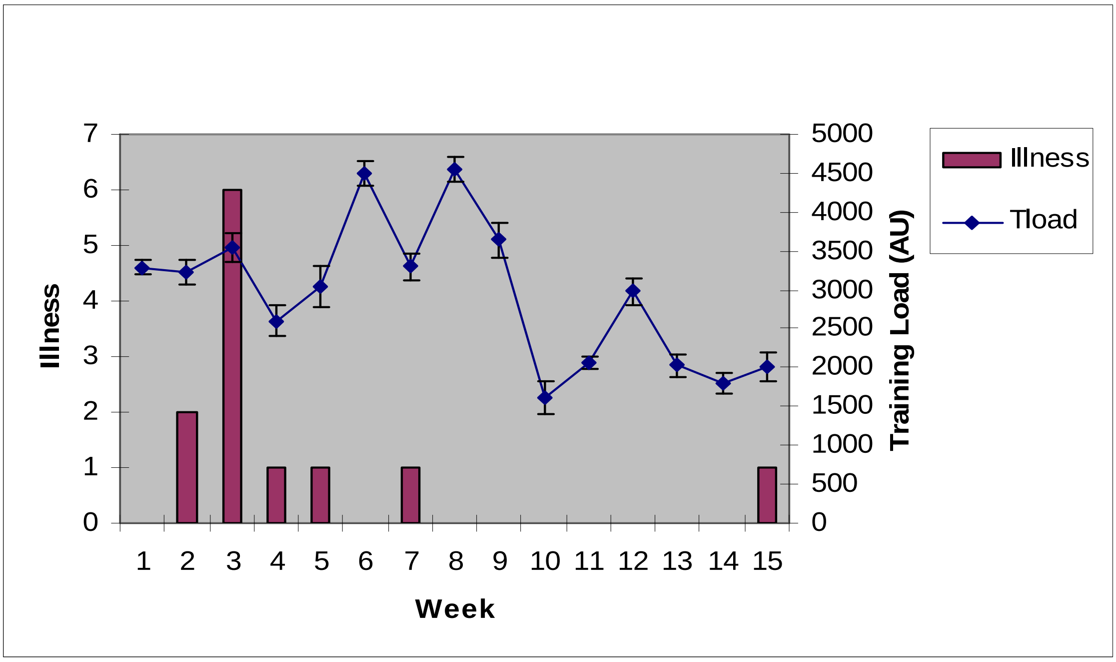

Figure 3. Training load (mean ± SEM) and incidence of illness over the 15 week pre-season

Whilst the relationship between training load and illness was found not to be significant, six incidences of illnesses occurred in week three of the pre-season. This coincided with a 10% increase in training load in week three compared with the previous week. The training load increase was moderate in terms of effect size (ES = 0.45). Corresponding spikes (>10% change) in the indices of training load and subsequent (within seven days) incidence of injury and illness (Foster, 1998), showed that 42% of illnesses and 40% of injuries in the present study could be explained by a preceding spike in training load.

There was a significant relationship (r = -0.52, *p* = 0.047) between total kilometres run and injury (Figure 4), however there was no significant relationship between total kilometres run and illness (Figure 5). The average weekly distance run was 26.8 ± 5.5 km. Peaks in kilometres run over the pre-season occurred in week 6 (34.2 km) and in week 8 (36.0 km) with lows occurring in week 5 (15.0km) and week 10 (19.0km).

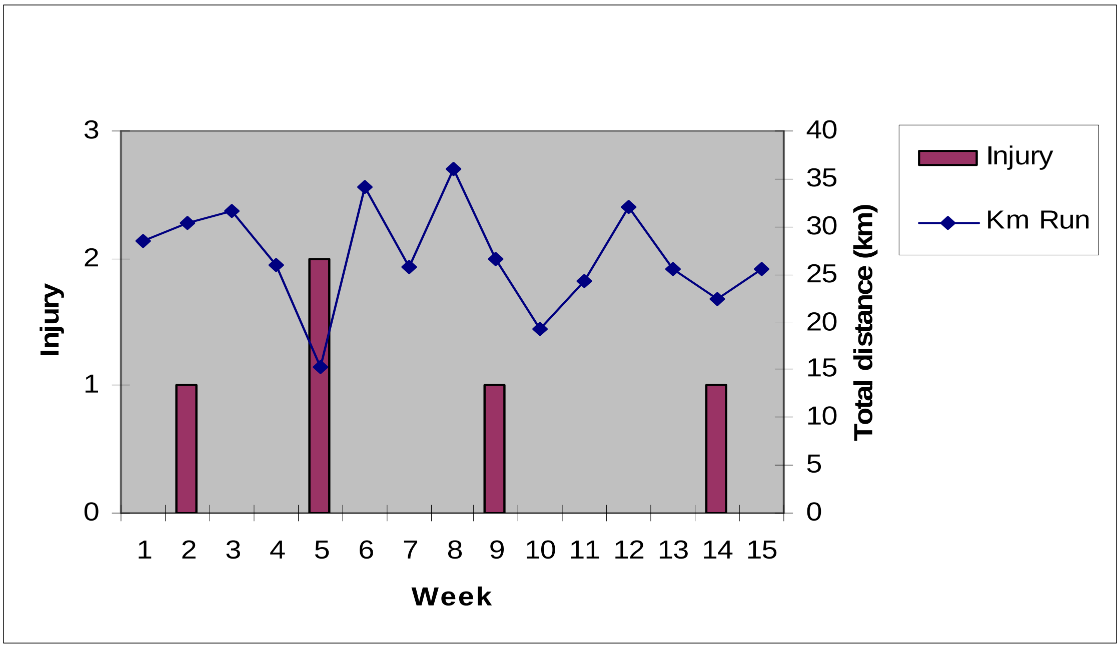

Figure 4. Total distance run (km) and incidence of injury over the 15 week pre-season

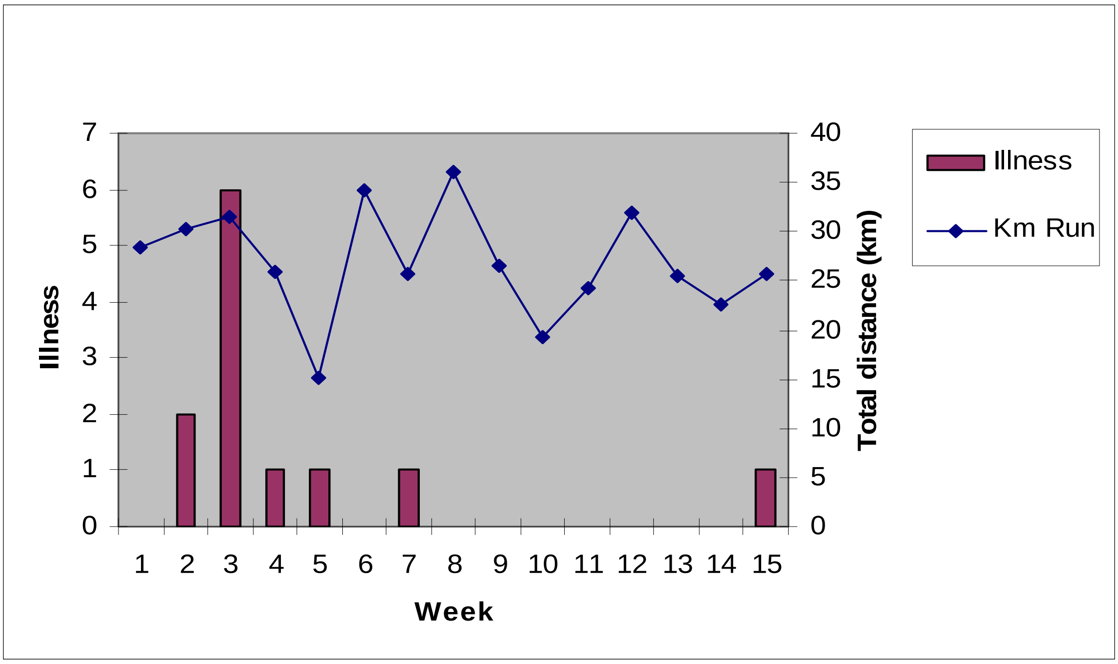

Figure 5. Total distance run (km) and incidence of illness over the 15 week pre-season

There were no significant relationships between distance run greater than 12 km/hr and either injury (Figure 6) or illness (Figure 7). The average weekly distance run greater than 12km/hr was 11.1 ± 3.2 km. There were three peaks in this indice of training load which occurred in weeks 2 (15.8 km), 6 (15.4 km) and 8 (15.5km). The nadir of 6.0 km occurred in week 5.

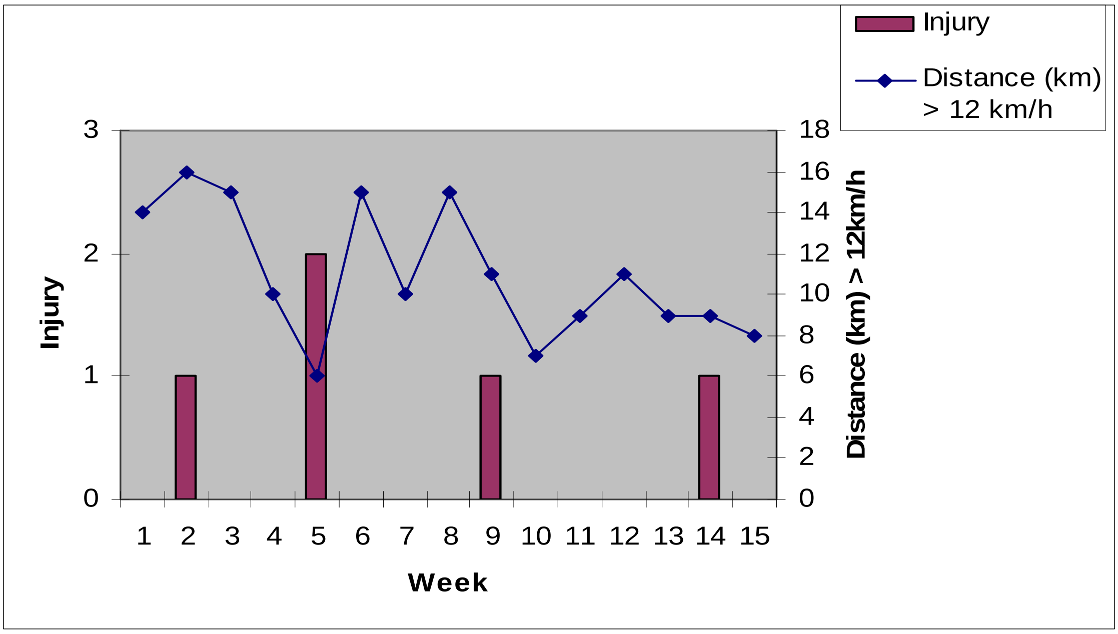

Figure 6. Total distance run (km) > 12km/h and incidence of injury over the 15 week pre-season

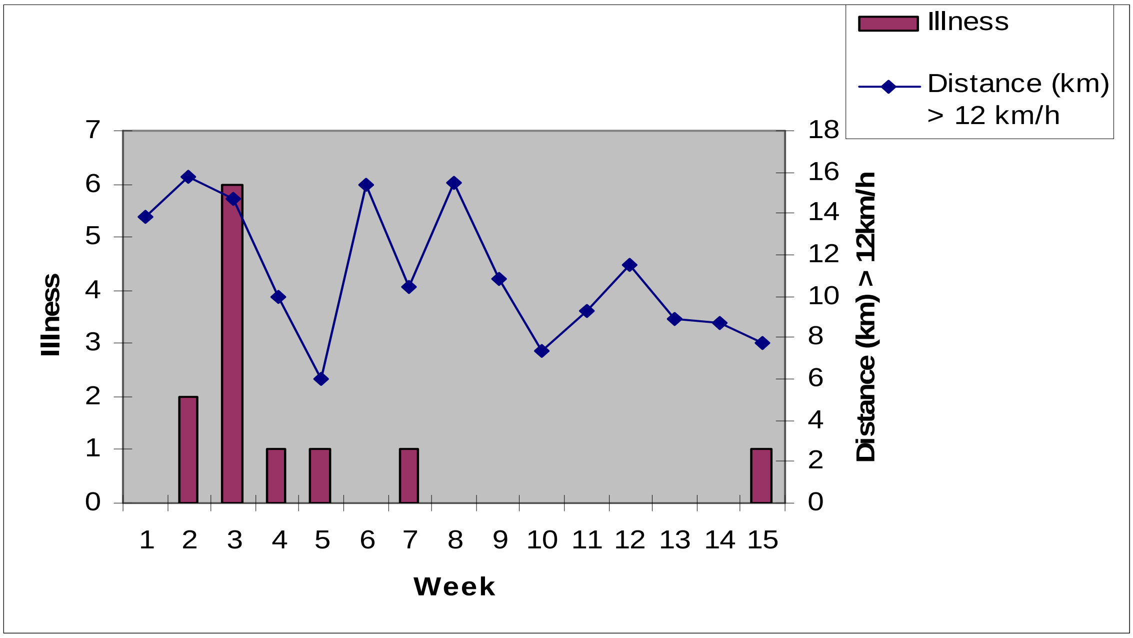

Figure 7. Total distance run (km) > 12km/h and incidence of illness over the 15 week pre-season

There were no significant relationships between minutes spent above 80% maximum heart rate and injury (Figure 8) or illness (Figure 9). The average weekly time spent above 80% maximum heart rate over the pre-season was 149 ± 38 minutes. Peaks in this indice of training load occurred in weeks 6 (223 minutes) and 8 (211 minutes) with the nadir occurring in week 10 (95 minutes). A one-way repeated measures ANOVA revealed that there was a significant difference from the peaks in weeks 6 and 8 and the nadir of week 10 ($p < .001$). Similarly to the figure of training load, following the peak in week 8 of the pre-season, there was a general downward trend in time spent above 80% maximum heart rate to week 11 when the pre-season games commenced.

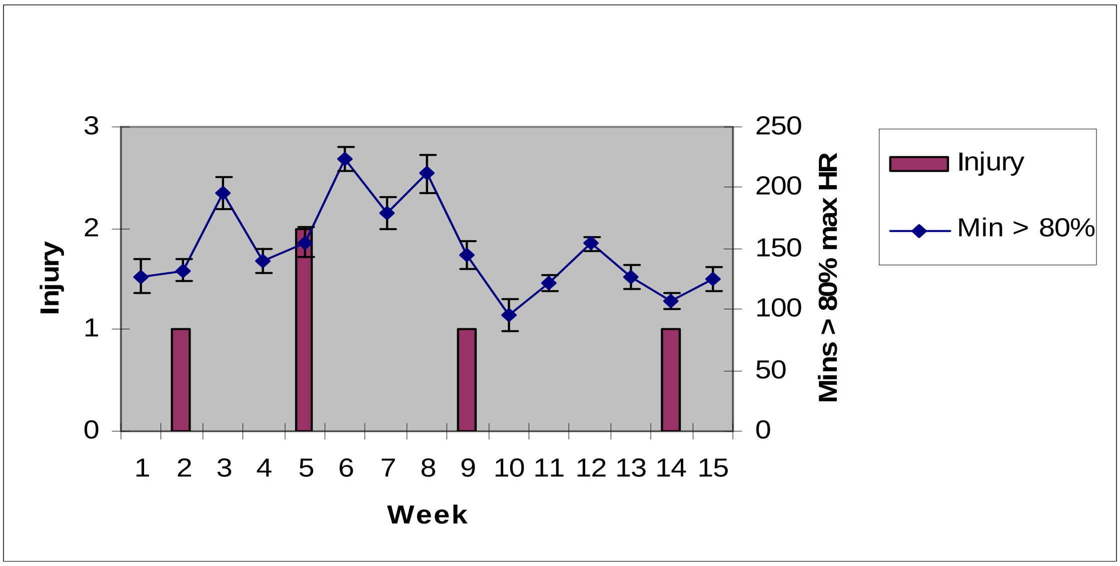

Figure 8. Minutes (mean ± SEM) spent above 80% maximal heart rate and injury over the 15 week pre-season

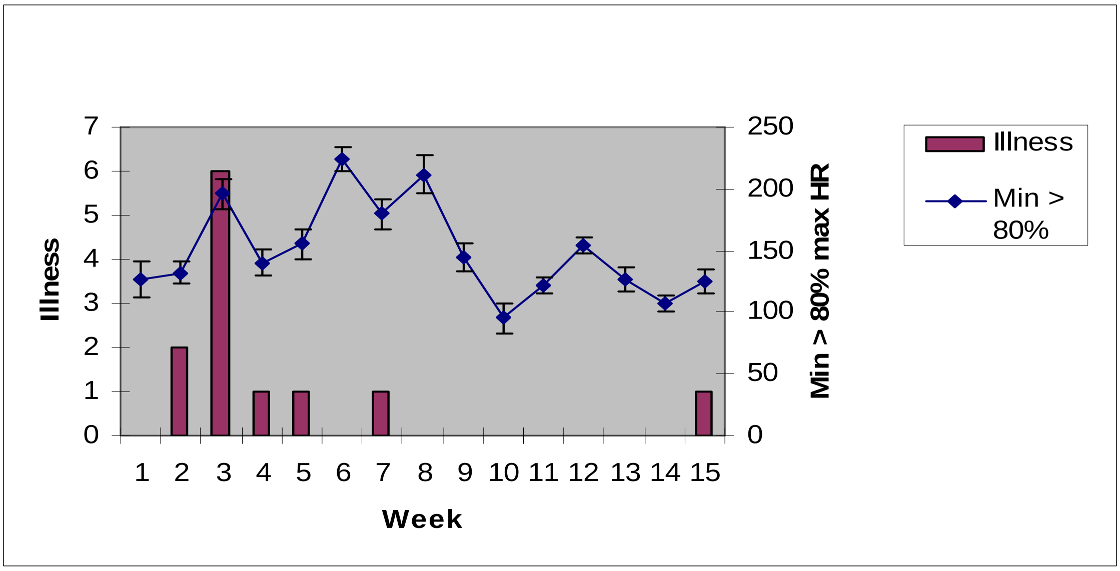

Figure 9. Minutes (mean ± SEM) spent above 80% maximal heart rate and illness over the 15 week pre-season

Monotony values for pre-season are shown below in Figures 10 and 11. The mean weekly monotony value for the study over the 15 week period was 1.19 ± 0.26 units. Weeks four and fourteen were notable for larger variance than the other weeks. No significant correlations were evident between monotony and injury (r = 0.25) and monotony and illness (r =0.12). The peak monotony value of 1.51 units occurred in week 1. Following this initial peak, there was a general downward trend in monotony values with a low of 0.79 units occurring in the last week of pre-season. A one-way repeated measures ANOVA revealed that there was a significant difference from the peak in week 1 and the nadir of week 15 ($p < .001$).

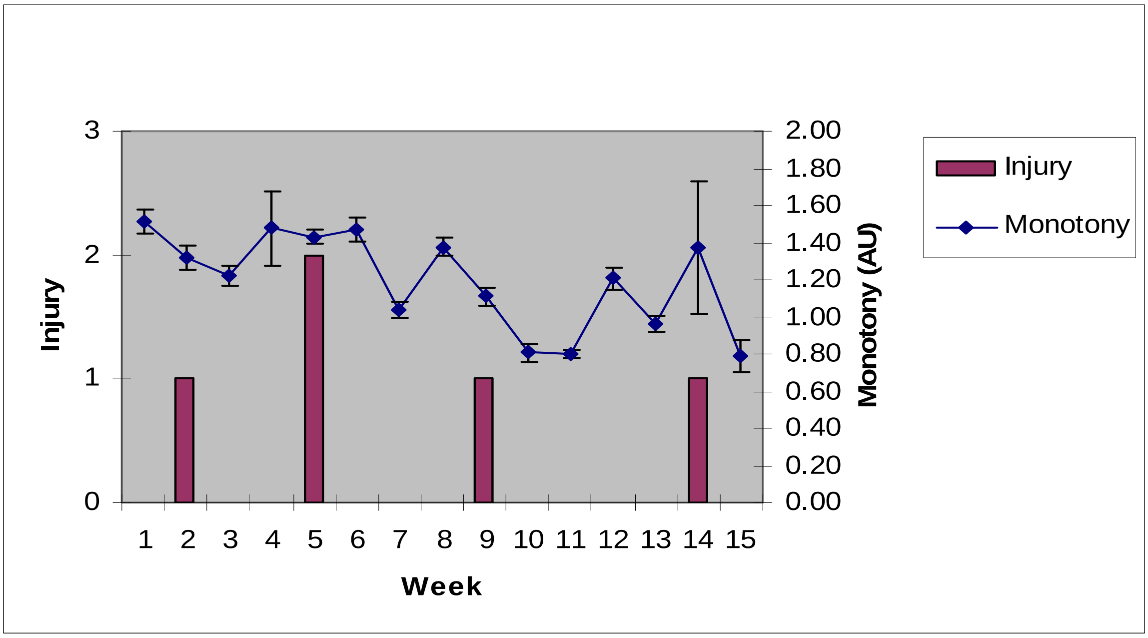

Figure 10. Monotony (mean ± SEM) and injury over the 15 week pre-season

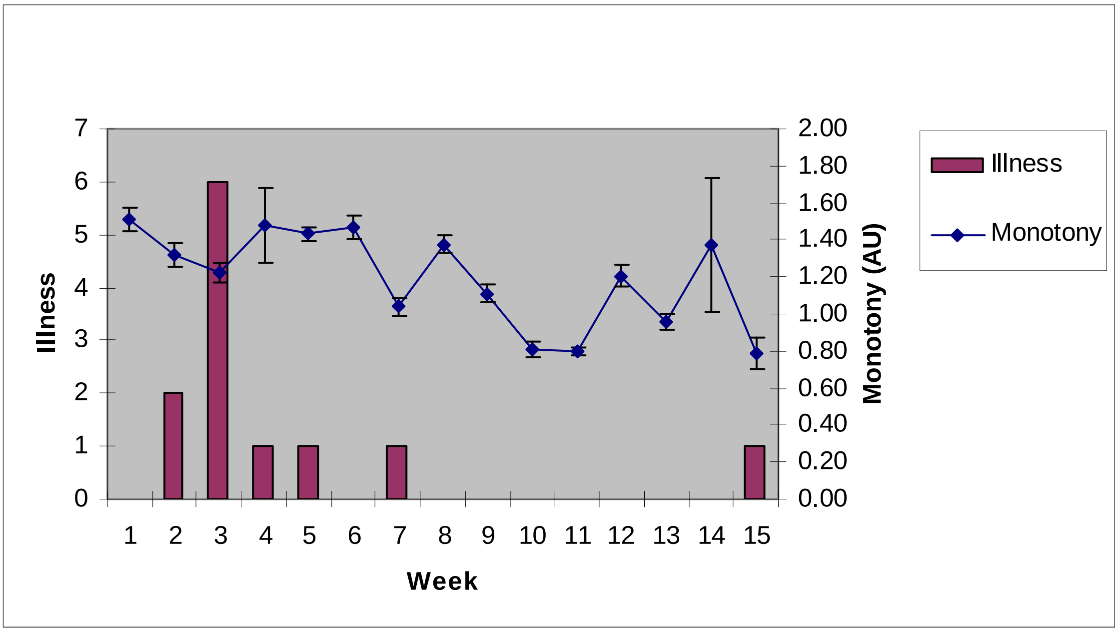

Figure 11. Monotony (mean ± SEM) and illness over the 15 week pre-season

Using the approach of correlating the incidence of injuries and illnesses to training (Foster, 1998), 33% of illnesses could be explained by a preceding spike in monotony, whilst 20% of injuries could be explained by a preceding spike in monotony.

Strain values are shown in Figure 12 and 13. The mean strain value over the 15 week period was 3654 ± 1654 units. Peaks in strain values occurred in weeks 6 (6697 units) and 8 (6631 units) with the lowest values occurring in weeks 10 (1378 units) and 15 (1641 units). A one-way repeated measures ANOVA revealed that there was a significant difference in strain values from the peaks in weeks 6 and 8 to the lows of weeks 10 and 15 ($p < .001$). Similarly to previous measures of training load, following the peak in week 8 of the pre-season, there was a general downward trend in strain values.

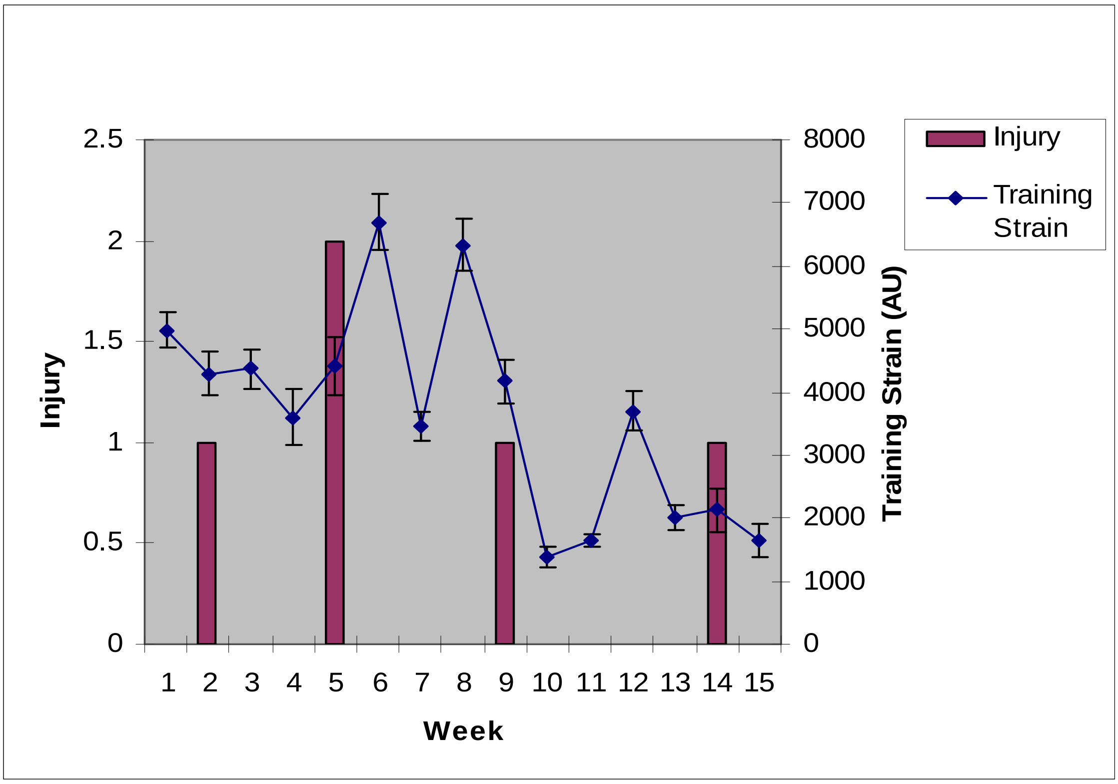

Figure 12. Training strain (mean ± SEM) and injury over the 15 week pre-season

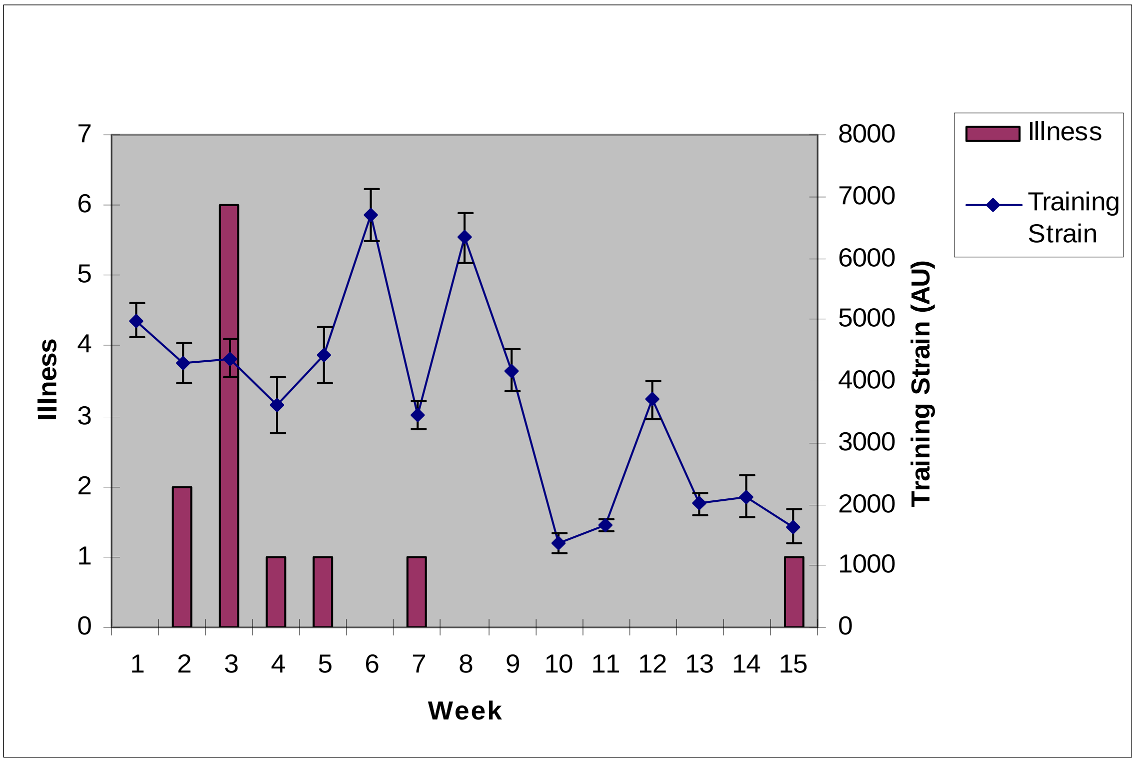

Figure 13. Training strain (mean ± SEM) and illness over the 15 week pre-season

When data from Figures 12 and 13 were analysed no significant correlations were observed between strain and injury (r = 0.07) and strain and illness (r = 0.12). As determined by the method of Foster (1998), twenty five percent of illnesses and 40% of injuries could be explained by a preceding spike in strain.

CHAPTER FIVE
DISCUSSION

The purpose of this study was to investigate the relationship between training load and the incidence of injury and illness in a group of AFL players. The pre-season training followed a planned and periodised training program lasting fifteen weeks and including four pre-season games. There were two peaks in training load which occurred in week 6 and week 8 and pre-season games commenced in week eleven. All indices of training load that were recorded in the study followed similar trends, peaking in week 6 and 8. This study concluded that training load does not affect the incidence of injury and illness at an AFL Club. The only significant relationship ($r = -0.52$), existed between distance run (km) and injury ($p < 0.05$). All other relationships between training load (as measured by RPE × time, minutes > 80% max HR, distance run > 12km/hr), monotony and strain and incidence of injury and illness were found to be non-significant. Forty two percent of illnesses and forty percent of injuries of illnesses could be explained by a preceding spike in training load, whilst 40% of injuries could be explained by a preceding spike in training load.

5.1 <u>Training Load and Injury</u>

There was a significant negative relationship ($r = -0.52$) between total kilometres run and injury; the more kilometres that the players run, the less incidence of injury ($p < 0.05$). It would appear that athletes adapted to the periodized training programme as the pre-season progressed and their bodies were able to withstand the increased distances run without being injured. Apart from the relationship outlined above, there were no other significant relationships between training and injury which conflicts with some previous research (Anderson, Triplett-McBride, Foster, Doberstein, & Brice, 2003; Gabbett 2004a; Gabbett & Domrow, 2007).

It is difficult to compare the actual training load doses between the present study and previous research (Anderson, Triplett-McBride, Foster, Doberstein, & Brice, 2003; Gabbett 2004a; Gabbett & Domrow, 2007) due to the different experimental designs.

However, Gabbett & Domrow (2007) reported pre-season training loads of 1891-2113 arbitrary units which is slightly lower in comparison to the current study's mean weekly training load of 2945 ± 922 arbitrary units. Anderson, Triplett-McBride, Foster, Doberstein, & Brice (2003) did not report actual training load doses; however interpretation from figures in their research suggests that the training loads were not as high as the present study. The fact that the present study was conducted using subjects who were all full time professional athletes compared to the previous research which involved semi-professional and NCAA Division III subjects, is one reason why the training loads may be higher.

Gabbett (2004a) found that the incidence of training injuries was highly correlated (r = 0.86) with the intensity, duration and load of training in semi-professional rugby league players. Gabbett & Domrow (2007) found that an increase in training load, particularly during the pre-season training phase, increased the odds of injury in collision sport athletes. AFL can be regarded as a collision sport, even though the number of collisions would not be as high as in rugby league. The large pre-season training loads demonstrated in Gabbett & Domrow (2007) were associated with a high incidence of lower limb injuries, muscular strains and joint sprains. Anderson, Triplett-McBride, Foster, Doberstein, & Brice (2003) also found that there was an increase in injuries during times of increased training loads (r = 0.68) during a basketball season, particularly in the first two weeks of formal practice when the training loads were highest.

There are several possible explanations as to why there were very few injuries in the present study. One of the main reasons is that the current study was conducted at an Australian Football League Club where there are three full time strength and conditioning staff as well as the club physiotherapist. All of these staff members constantly screened players in an attempt to identify risk factors predisposing athletes to injury. If any athlete was found to be at risk, their training programme was modified with the aim of lowering the chance of injury occurring. The club has found that the primary type of injury prevented via this screening is that of a soft tissue nature. Gabbett & Domrow (2007) identify soft tissue injuries as having a high incidence during pre-season (lower-limb injuries, muscular strains and joint sprains). If the screening process did not occur, it is likely that the incidence of injury in this particular study would have been appreciably higher, possibly increasing the strength of the relationship between training load and injury. It is possible that previous studies (Anderson, Triplett-McBride, Foster, Doberstein, & Brice, 2003; Gabbett 2004a; Gabbett & Domrow, 2007) that recorded significant relationships between training load and injury did not screen as thoroughly and regularly to identify “at risk” athletes as that which occurred in this current study, possibly due to the availability of resources . An example of this could be Gabbett’s (2004a) research where one head trainer worked with 79 players providing injury prevention and management services as well as working as a skills and conditioning coach and also assessed all injuries. The availability of strength and conditioning and medical resources may have affected the injury screening process in the studies cited above which could affect the incidence of injury.

Another possible explanation for the low injury incidence during pre-season in this particular study is that the athletes involved have individual training programmes, designed to maximise strength and fitness gains and minimise incidence of injury. The screening process is used to identify areas of concern that predispose athletes to injury. These areas are then targeted in the athlete’s individual programming. For example, if hamstring flexibility is identified as an area of concern for a particular athlete, then this becomes one of their target areas in the programme design.

Gabbett (2004a) suggested that one of the reasons for the large increase in injuries during a 12 week period (December to February, 38.5% increase in training load corresponding with a 95% increase in incidence of injuries) in rugby league players was that the increase in training load was greater than was tolerable for the musculoskeletal system. In the study by Gabbett (2004a), the 79 subjects were made up of players of which at least 20 were eligible for selection in the under 19 team. In comparison, subjects in this current study had an average AFL age of 5.2 years, meaning that they had been on an AFL list and a professional sportsman for 5.2 years. These athletes were already at a high level of fitness; their musculoskeletal system was able to tolerate large loads, thus potentially avoiding high incidence of injury. Therefore the musculoskeletal maturity of the present study’s subjects in comparison to subjects in Gabbett’s (2004a) study could be another possible reason for the contrasting relationships between training load and injuries when comparing studies.

A major finding of Gabbett & Domrow's (2007) research was that a low estimated VO2 max in sub elite rugby league players increased the risk of contact injuries. This was further expanded by stating that sub elite rugby league players with low speed and maximal aerobic power are at an increased risk of injury. Therefore, another possible explanation as to why there was not a high incidence of injuries in this study as compared to Gabbett & Domrow (2007) is that the subjects in this study were already at a high fitness level when the pre season commenced in comparison to the sub elite rugby league players.

A further explanation for the low incidence of injuries during the pre-season can be linked to the coaching and conditioning philosophy of the club at the time of the study in using skill based team training sessions as one of the main methods of conditioning. Gabbett (2002) suggested that skill-based conditioning games are seen as an effective method of conditioning as they offer an additional challenge to team sport athletes that would not normally be present in non-skill related conditioning activities. Players are required to think under pressure and fatigue, while competing in an intense game that simulates the specific movement patterns and intermittent nature of their sport. Gabbett (2002) found that skill based conditioning games are associated with a low incidence of injury and that they are a safe and effective method of conditioning for rugby league players. The present study supports the research of Gabbett (2002) and based on the results of the present research it is suggested that skill based conditioning games are an effective method of conditioning that has a low injury incidence in AFL players.

It could be argued that one of the major reasons why athletes were able to cope with the applied training load and not incur injury is that there was low monotony in the training programme (mean weekly value = 1.19), or in simple terms there was a high variation in the programme. This supports the work of Anderson, Triplett-McBride, Foster, Doberstein, & Brice (2003) who despite finding a strong link between training load and injury, were unable to detect any overtraining symptoms (which could lead to higher injury levels). One of the explanations given for this occurrence by Anderson, Triplett-McBride, Foster, Doberstein, & Brice (2003) was that high levels of monotony did not exist in that particular basketball season which may be part of the reason overtraining conditions were not observed. Further supporting evidence comes from Suzuki, Sato, Maeda, & Takahashi (2006), who recorded a mean level of monotony of 0.74 ± 0.4 units and no incidence of injury. Therefore, it can be concluded that providing a high degree of variation in the training load applied to athletes can lead to a lower incidence of injury.

The definition that was used in this study for classifying injury may also have contributed to the relatively low injury count. Injury was defined as any pain or disability suffered by a player during a training session or game that restricts full participation in the future general training programme. Several athletes though completed alternate training sessions when they were deemed “at risk” of injury which was a decision made by the club physiotherapist in conjunction with the strength and conditioning staff. These athletes were not suffering pain or disability as was required in the definition of injury used in the study; however they were deemed “at risk”. It could be argued that if these athletes completed the planned session and not the alternate sessions then the injury count may have been higher. However, in the professional sporting environment injuries to athletes can have severe consequences and it would be very naïve not to screen athletes and allow them to participate when there is greater chance of injury.

5.2 Training load and Illness

There were no significant relationships between training loads and the incidence of illness in this particular study. These results are similar to other studies that have been completed in this area. Anderson, Triplett-McBride, Foster, Doberstein, & Brice (2003) found that the number of athletes suffering from illnesses fluctuated in an unpredictable manner over a season. Putlur et al., (2004) found that illnesses were not significantly correlated to S-IgA, which is often seen as a pre-cursor to illness. Even though Putlur et al., (2004) found that that no illnesses were recorded during weeks 7, 8 and 9 of the season (when training load was reduced), 55% of illnesses recorded could be explained by a preceding spike in training load.

Mackinnon (1997) indicated that there is a general perception among athletes, coaches and sports physicians that athletes are susceptible to infectious illness during intensive training and major competitions. Shephard & Shek (1993) suggested that moderate exercise may stimulate the immune system but hard training actually suppress it, thus increasing the risk of infection. In the present study, six illnesses occurred during week three of the pre-season which is when training load had peaked for the first time. It could be argued that week three was the first instance of "hard" training which may have suppressed the immune system; whilst the previous weeks have been "moderate" training which may have stimulated the immune system (Shephard & Shek, 1993).

ES calculations showed that the training load increase (10%) from week two to week three was moderate (ES=0.45). It could be argued that after this initial spike in training load, athletes adapted to the greater training load resulting in increased fitness. Sessions completed early in the pre-season may have been considered "hard" resulting in suppression of the immune system and increasing the risk of infection. Equivalent sessions performed later in the pre-season could have been considered "moderate" and actually stimulated the immune system leading to a reduced risk of infection. Support for such a contention lies in the finding that after the spike of six illnesses in week three, the greatest number of illnesses recorded in any week was one. This suggests that the athlete's bodies and immune systems had adapted to the increased workload. Indirect evidence for this suggestion comes from the work of Bruin, Kuipers, Keizer, & Vander Vusse (1994). One of the conclusions from their work involving training adaptations with equine athletes was that a progressive increase in training loads could be tolerated by the horses as long as days of intensive exercise were alternated with days of endurance running at moderate speeds.

Corresponding spikes (>10% change) in the indices of training load and subsequent incidence of illness, showed that 42% of illnesses could be explained by a preceding spike in training load. In comparison, Foster (1998) found that 84% of illnesses could be explained by a preceding spike in training load and demonstrated that a high percentage of illnesses could be accounted for when individual athletes exceeded identifiable training thresholds. One possible explanation for the difference could be the different research designs. Foster (1998) employed a larger sample size in (25 versus 16) and a longer data collection period (ranging between six months to three years versus 15 weeks) than the present study, which probably explains the greater incidence of illness. With regard to the percentage of illnesses that can be explained by a spike in load, the results of the present study (42%) are similar to that of Putlur et al. (2004) who reported a value of 55%. Spikes in training load can be useful in predicting illness however research designs need to investigated when comparing studies.

5.3 Monotony and Strain

As discussed previously, the weekly mean monotony value recorded in this study was 1.19 ± 0.26. This value is comparable to monotony values of other elite training programs including a 400 m sprinter (0.74) (Suzuki, Sato, Maeda, & Takahashi, 2006), a speed skater (1.44) (Foster, 1998) and semi professional rugby league players (1.72) (Coutts, 2001). The 400 m sprinter had two complete rest days off in their training week which could explain the relatively low monotony value compared to the current study (Suzuki, Sato, Maeda, & Takahashi, 2006). The slight difference in monotony values of the elite speed skater in Foster's (Foster, 1998) study compared to the current study could be that the speed skater trained everyday (some were lighter than others), which would have increased the weekly monotony level. This is in comparison to the current study, who as well as having lighter training days during the week, also had one complete day off to aid the recovery process. The semi-professional rugby league training week in Coutts' (2001) study had a larger weekly monotony value than the current study possibly due to the fact that the example week used was an 'in season' week compared to the pre-season phase in which the current study was undertaken.

The mean monotony value of the present study suggests that there was appreciable variability in training sessions over the pre-season. That no significant relationship was found between monotony and injury adds support to the research of Anderson, Triplett-McBride, Foster, Doberstein, & Brice (2003) who reported high levels of monotony were not existent in their study which may be in part why overtraining conditions were not observed. These same researchers suggested that altered practice sessions and strength training programmes may be the answer to decreasing the athletes' susceptibility to injury and overtraining. In this research project, few injuries were recorded and it is postulated that one of the contributing reasons to this was a relatively high variability in training.

It was found that 20% of injuries and 33 % of illnesses could be explained by a preceding spike in monotony. The low percentage of injury prediction from monotony values may be explained by the low injury rate; which in turn could be linked to the definition and other factors which have been explained previously. When comparing the percentage of illnesses that can be explained this way, the figure of 33% from the present study is considerably lower that Foster's (1998) result of 77%. As discussed previously, differences in experimental design of the two research projects could be a contributing factor to the difference in results.

The mean strain value over the 15 week period for this current study was 3654 ± 1654 units. This is in comparison to Coutts' (2001) example of a typical 'in season' training week of a semi professional rugby league player which is 4920 units. A possible explanation for the higher strain value recorded in Coutts' (2001) research could be that the example given was an 'in season' week, which included the game, as opposed to a pre-season period when the current study took place. Foster (1998) calculated the weekly strain value from elite speed skater as 5397 units, which is considerably higher than the mean strain value recorded in this current study. As strain is the product of monotony and weekly load, both of these factors are possible reasons for the speed skater's strain value. The elite speed skater trained everyday, which as well as affecting the monotony level, also contributes to a greater weekly training load. When monotony and weekly load are multiplied to obtain strain, it can be seen how the elite speed skater in Foster's (1998) study, has a higher strain value than the mean strain value of the current study.

With regard to strain values, 25% of illnesses could be explained by a preceding spike in strain which once again is lower than other previous research of (Foster (1998) of 89% and Putlur et al., (2004) of 64%). Possible explanations for these differences are again potentially due to the differences in experimental designs and training status of the subjects.

CHAPTER SIX
CONCLUSIONS AND PRACTICAL RECOMMENDATIONS

This study provided valuable insight into the training demands over a pre-season at an AFL club. It can be concluded that training load as calculated by RPE × time, mins > 80% max HR, total distance run and total distance run > 12km/hr are effective ways of monitoring the training of athletes as injuries and illness were at a minimum in this study. Strain and monotony are also valuable and effective methods of monitoring training load of athletes. It can also be concluded that a training programme that has a high degree of variation (relatively low monotony values) may contribute to the low incidence of illness. It may be possible to predict the incidence of some injuries and illnesses in a training programme from preceding spikes in training load. A further conclusion from this study is that the highest incidence of illness occurred when training load first peaked in the pre-season (week 3) and then player's bodies and immune systems are able to adapt to the increasing stresses being place upon them.

There are some practical recommendations that have resulted from the completion of this study. One of these recommendations is confirmation that the implementation of a planned and periodized training programme that is monitored accurately can keep injuries and illness of athletes to a minimum. Individual monitoring of athletes in team sports is essential as all athletes respond differently to the training stresses that are applied. Regular and systematic screening of athletes is a vital factor in keeping the incidence of injury to a minimum and this area of research warrants further attention, particularly in elite populations.

7 CHAPTER SEVEN
RECOMMENDATIONS

Based on the findings of this study there are some recommendations that can be put forward for future research that investigates the monitoring of training load in team sports.

7.1 Definitions

The first of these recommendations relates to the actual definitions of injury and illness. In this study there was a very small incidence of injuries throughout the pre-season. The definition of injury used in this study was defined as any pain or disability suffered by a player during a training session or game that restricts full participation in the future general training programme. Several athletes completed alternate training sessions when they were deemed "at risk" of injury, which was a decision made by the club physiotherapist in conjunction with the strength and conditioning staff. These athletes were not suffering pain or disability as was required in the definition of injury used in the study; however they were deemed "at risk". It is felt that for future studies involving the monitoring of training load and incidence of injury that there needs to be a sub-classification of injury, possibly called "at risk", and this could be used in addition to the above definition. Alternatively, the number of planned sessions that athletes miss due to being in the "at risk" of injury category could be calculated and analysed as another dependent variable.

With regard to illness, this study used the definition as occurrence where the player misses a training session or game due to a medical condition that was diagnosed by the club's doctor (eg upper respiratory tract infection, influenza, gastroenteritis). Whilst this is an effective method of obtaining illness statistics, it may be beneficial for future studies to categorise the illnesses possibly into those that are "immune deficiency illnesses" and "other illnesses". In this study, illnesses that are not necessarily related to the immune system, still result in an athlete missing sessions and count as an illness statistic. Previous research has shown links between training load and the immune system (Pyne & Gleeson, 1998; Shephard & Shek, 1994) and if accurate research is to be completed in this area then there needs to be classification of illnesses as to whether they are as a result of a deficiency in the immune system.

7.2 Hormonal Measures

A further recommendation from the completion of this study is that future studies to include some kind of regular biochemical measure, such as cortisol or S-IgA, in addition to the illness statistics. This method has been used previously in research (McGuigan, Egan & Foster, 2004; Putlur et al., 2004; Coutts, Reaburn, Piva & Murphy, 2007) and could be used in combination with the injury and illness statistics to give a detailed analysis as to how the athlete is coping with the stresses of the training programme. The club's staff could possibly even put in some illness prevention strategies if hormonal measures of a particular athlete show they are at risk of illness.

7.3 Monitoring of all Training Activities

A further recommendation is that all activities that athletes participate in during the pre-season training programme should be included in the research. In this particular research project, data was gathered from team skills sessions, team conditioning sessions as well as resistance training sessions. In addition to this athletes may have individual skills sessions, which although generally considered light in terms of training load, definitely contribute to the overall load on athletes. Athletes in professional team sports usually have some time of injury prevention exercises like yoga or balance exercises in their programme and it is felt for future studies that these aspects should be included in the study. By including all aspects of the strength and conditioning programme, the researcher will then be obtaining more accurate data about the athlete's total training load.

In addition to this, when monitoring training load using GPS units all subjects need to be monitored for all sessions where there is an element of running involved including team skills sessions and conditioning sessions. In this particular study, there were 16 subjects and five GPS units were allocated for amongst subjects for each session. Whilst this provided average data for what the team skills sessions and conditioning sessions involve, more accurate data would have been gathered when all players are wearing GPS. There can be major differences in kilometres run in team sports where different positions are played. Whilst this was attempted to be accounted for in this particular study, it is felt that this could be overcome by all athletes wearing a

GPS. The fact that only five players were GPS units per session was a limitation of the study.

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APPENDICES

APPENDIX A

Information Letter

Edith Cowan University
100 Joondalup Drive
JOONDALUP WA 6027

Information Letter

Dear Participant

As part of my job as an assistant Strength and Conditioning Coach at an AFL Club, data is collected from training sessions and games using heart rate monitors, Global Positioning Systems (GPS) and training load using the Rate of Perceived Exertion Scale (RPE). I would like to use the information that is gathered in a research project that explores the relationship between training load and the incidence of injury and illness over a pre-season. The title of the project is "***The relationship between training load and the incidence of injury and illness over a pre-season at an Australian Football League Club".***

The research project will be undertaken as part of the fulfillment of a Masters in Sport Science (Research) through Edith Cowan University. The supervisors are Dr Mike McGuigan (m.mcguigan@ecu.edu.au, Ph: 08 6304 2118) and Mr Mike Newton m.newton@ecu.edu.au, Ph: 08 6304 5461), both faculty members of the School of Exercise, Biomedical and Health Sciences.

As part of the research project, training will be monitored as it is now, in all team training sessions using heart rate monitors and GPS systems. As well as this, participants will be required to enter an RPE into the training database approximately 30 minutes after each training session, as it is done currently. Combined with this, injury records will be kept by the club's physiotherapist and illness records will be kept by the club's doctor. At the conclusion of the pre-season period all of the information will be analysed to explore the strength of the relationship between training load, injury and illness. It is hoped that the pre-season for the 2007 season can be used to collect the data, with the remainder of that year to be used for data analysis and the writing of the thesis.

There has been no funding granted for this research project by either the club or the university. The benefits of the project are that accurate information can be gathered about the training loads of an Australian Football League Club (AFL) in pre-season and the link to injury and illness. This can help in future planning of pre-season training to make the club aware of training loads where injury and illness are more likely to occur. There are no additional risks associated in the participation of the research project, other than those that are ordinarily present in your current employment as a professional AFL player.

Confidentiality will be kept as the information will be de-identified meaning that names will be replaced by numbers in the analysis of data. Hopefully, the results will be published in a thesis as part of the Masters project. In any publication, the club or participants will not be identified.

Your participation as a subject in this research project is completely voluntary and you are free to withdraw at any time without explanation. First year players, as well as veterans were not included as their pre-season is modified.

If there are any concerns about the research project, please feel free to contact myself (bpiggot0@student.ecu.edu.au, Ph 04037 03656), Dr Mike McGuigan or Mr Mike Newton. Ethics approval for the project has been granted and any concerns in this area can be directed to:

Research Ethics Officer
Edith Cowan University
100 Joondalup Drive
Joondalup WA 6027
Email : research.ethics@ecu.edu.au
Ph: 08 6304 2170

Thank you for your efforts and cooperation in participating in this research project and I look forward to working with you in the data collection process.

Regards

Ben Piggott

APPENDIX B

Informed Consent Form

Edith Cowan University
100 Joondalup Drive
JOONDALUP WA 6027

Informed Consent Form

The relationship between training load and the incidence of injury and illness over a pre-season at an Australian Football League Club

You are invited to participate in a study that will investigate the relationship between training load and the incidence of injury and illness over a pre-season at an Australian Football League Club.

Currently, training data such as the type of session, length of session, rating of perceived exertion, heart rate and global positioning systems (GPS) data are recorded on the club's database by the strength and conditioning staff with input from yourselves (as per normal). If you decide to participate in the study, this training data will be taken, along with injury and illness statistics, and analysed to explore the strength of the relationships between training load, injury and illness. Any illness will be diagnosed by the club doctor and any will injury be diagnosed by the club physiotherapist. All of these statistics will be recorded in the club's training database. The study will commence at the first official training session for the year and conclude at the end of the last pre-season competition game.

The research is being conducted in fulfillment of a Masters Degree within the School of Exercise, Biomedical and Health Science at Edith Cowan University. The supervisors of the research are Dr Mike McGuigan and Mr Mike Newton , both faculty members of the School of Exercise, Biomedical and Health Sciences.

All information that is recorded is confidential and in the analysis process subject's identity will remain disclosed. The project is concerned with the number of injuries and illnesses related to the training load; not who they are. It is possible that the Masters project will be published in a dissertation, and again subjects' identity will be kept confidential.

An information letter that outlines the procedures involved in the study has been given to all subjects, as well as an opportunity to ask any questions.

If you decide to participate in the study your involvement will be as follows:

- Participation in pre-season training program as prescribed to the club's coaching and strength and conditioning staff.
- Recording of training data on database including type of session, length of session and rate of perceived exertion rating.
- Consult medical staff if you suffer any illness and or injury during the pre-season (as per normal club procedure).

Participation in the project is strictly voluntary and subjects are free to withdraw from participation at any time, without explanation or penalty.

Any questions regarding the study can be directed to the following:

Dr Mike McGuigan m.mcguigan@ecu.edu.au, Ph: 08 6304 2118

Mr Mike Newton m.newton@ecu.edu.au, Ph: 08 6304 5461

Ben Piggott (Student No. 1002 5438) bpiggot0@student.ecu.edu.au Ph: 04037 03656

If you agree to participate in the study, please sign the informed consent form below:

I have been fully informed of the procedures involved in this study and I willingly and voluntarily agree to participate in this project.

Subject: ______________________________ Date: _______________

Investigator: ___________________________ Date: _______________