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Research article

Game and Training Load Differences in Elite Junior Australian Football

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Abstract
Game demands and training practices within team sports such as Australian football (AF) have changed considerably over recent decades, including the requirement of coaching staff to effectively control, manipulate and monitor training and competition loads. The purpose of this investigation was to assess the differences in external and internal physical load measures between game and training in elite junior AF. Twenty five male, adolescent players (mean ±SD: age 17.6 ± 0.5 y) recruited from three elite under 18 AF clubs participated. Global positioning system (GPS), heart rate (HR) and rating of perceived exertion (RPE) data were obtained from 32 game files during four games, and 84 training files during 19 training sessions. Matched-pairs statistics along with Cohen's *d* effect size and percent difference were used to compare game and training events. Players were exposed to a higher physical load in the game environment, for both external (GPS) and internal (HR, Session-RPE) load parameters, compared to in-season training. Session time (d = 1.23; percent difference = 31.4% (95% confidence intervals = 17.4 – 45.4)), total distance (3.5; 63.5% (17.4 – 45.4)), distance per minute (1.93; 33.0% (25.8 – 40.1)), high speed distance (2.24; 77.3% (60.3 – 94.2)), number of sprints (0.94; 43.6% (18.9 – 68.6)), mean HR (1.83; 14.3% (10.5 – 18.1)), minutes spent above 80% of predicted HRmax (2.65; 103.7% (89.9 – 117.6)) and Session-RPE (1.22; 48.1% (22.1 – 74.1)) were all higher in competition compared to training. While training should not be expected to fully replicate competition, the observed differences suggest that monitoring of physical load in both environments is warranted to allow comparisons and evaluate whether training objectives are being met.

Key words: Adolescent, youth athlete, GPS, time motion analysis, rating of perceived exertion, training prescription.

Introduction

Game demands and training practices within team sports such as Australian football (AF) have changed considerably over recent decades, including the requirement of the coaching staff to effectively control, manipulate and monitor training loads (Gray and Jenkins, 2010; Impellizzeri et al., 2004; Norton et al., 1999). The need to understand the mechanisms of internal training load within the team sport environment is of particular importance, as the external load is often similar for each member of the team due to the prescription and dominant use of group exercise and training (Impellizzeri et al., 2004). Studies have provided some insight into the game and training loads within youth sports such as men's and women's soccer (Alexiou and Coutts, 2008; Impellizzeri et al., 2004), rugby league (Gabbett and Domrow, 2007), rugby union (Hartwig et al., 2008; 2009; 2011) and basketball (Ben Abdelkrim et al., 2007; 2010, Gianoudis et al., 2008; Montgomery et al., 2010). These investigations have utilised objective and subjective measures such as global positioning system (GPS) time motion analysis, heart rate (HR) monitoring, training and physical activity diaries (including ratings of perceived exertion (RPE)) and blood lactate measures. However, despite the increased professionalism of adolescent sport and improved development pathway programs to elite adult participation, data on the elite junior player is under-explored (Burgess et al., 2012; Hartwig et al., 2009).

The physiological traits and training responses of adolescents are 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 while 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 in order to minimise the risk of injury and overtraining, and increase participation longevity (Burgess and Naughton, 2010; Kutz and Secrest, 2009). Monitoring the game and training load demands of AF players is important as it may allow coaching and conditioning staff to make more objective decisions regarding training prescription for the team, as well as guide individual player management such as those who could be at an increased risk of injury (Rogalski et al., 2013).

To date, no study has formally assessed the typical physical loads and subsequent differences between game and training sessions in elite junior AF, as only limited data is available on game demands (Burgess et al., 2012; Veale and Pearce, 2009a; 2009b, Veale et al., 2007). The purpose of this investigation was to describe training and competition loads in elite junior AF and to assess the differences in key internal and external physical load measures between game and training environments.

Methods

This study used a prospective longitudinal research design with data collected over a 19 week period of the under 18 Transport Accident Commission Cup (TAC Cup) AF season. The TAC Cup is a representative competition between 12 teams from regions in metropolitan and country Victoria, Australia. This sub-elite / elite competition is the preferred development pathway for talented junior

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players to be drafted to professional Australian Football League teams. One regional and two metropolitan teams participated in the research. Time motion (GPS) and HR analyses, along with RPE were used to assess elite junior AF player physical load within both game and training sessions. A paired sample for each player was used for comparison. GPS and HR data were obtained from a total of 32 game files from three clubs across four games (1.3 ± 0.5 games per player), and 84 training files across 19 training sessions (3.4 ± 2.7 training sessions per player). Both game and training sessions were conducted outdoors on grass ovals. Training data was collected mid-week in the late afternoon on either a Tuesday or Thursday, while game data was collected on a weekend in the early to mid-afternoon. The training sessions were part of the in-season periodisation phase prescribed by the coach, with no input from the researcher.

Participants

Twenty five male, adolescent AF players aged 17 to 19 years (age 17.6 ± 0.5 y, height 1.86 ± 0.06 m, body mass 78.0 ± 7.9 kg) recruited from three TAC Cup clubs participated in this study. All participants received a letter explaining the aims and requirements of the study and were present at a briefing session that outlined testing procedures prior to giving informed consent. A research assistant was in attendance on all data collection days to answer any questions and assist with data collection. Parental consent was obtained for participants under the age of 18 years. Ethics approval was given by the University's Human Research Ethics Committee.

Time motion analysis

GPS technology allows the measurement of speed and position in sport (Townshend et al., 2008). Players were fitted with an individual GPS data logger unit (SPI Elite unit, 1 Hz, GPSports, Canberra) during game and training sessions. Players were encouraged to wear the same device during repeat sessions, however for logistical reasons this was not always the case. An undergarment that housed the unit within a pouch between the shoulder blades was worn by the player. GPS data were summarised based on previous time motion analysis research in senior (Coutts et al., 2010) and junior AF (Gastin et al., 2013a) including low speed activity (0-14.4 $km{\cdot}h^{-1}$), high speed activity (> 14.4 $km{\cdot}h^{-1}$), and sprinting (> 23 $km{\cdot}h^{-1}$). The validity and reliability of the GPS device used to assess team sport activity and peak speed have previously been reported as acceptable (Barbero-Álvarez et al., 2010; Coutts and Duffield, 2010). Possible errors that may exist during short, high speed and change of direction running (Coutts and Duffield, 2010; Jennings et al., 2010) are acknowledged as a potential limitation, however likely to be consistent between training and competition environments and therefore unlikely to affect the interpretation of findings related to the primary research question.

Heart rate

Players were fitted with a HR 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 GPSports Spi Elite unit. Data are reported as mean and peak HR as well as time spent within three HR zones (50 – 80%, > 80%, > 90% HRmax) (Edwards, 1999). Maximal heart rate was estimated according to the predictive equation (HRmax = 209.9 – (0.73 x age)) for youth and adult athletes during running (Faff et al., 2007).

Rating of perceived exertion

Players completed an individual training diary where they subjectively recorded their mean intensity using a category ratio 0-10 RPE scale (Foster et al., 2001) and time duration for each training and game session, approximately 30 minutes post session. Session-RPE (RPE x session time (min)) was used to calculate a subjective estimate of session load (Foster et al., 2001). Session duration was also objectively assessed using each player's corresponding GPS data file.

Data processing

Software processing of the GPS and HR data was undertaken within the Team AMS analysis software program (version 2.1.0.6. R1 2010 P2 GPSports, Canberra), which summarised HR and time motion analysis data. Files were edited to exclude major breaks within training and games to provide a true representation of GPS 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 expected. Typically these were the formal breaks within a game (e.g., quarter, half and three-quarter time breaks), when a player was on the interchange bench or when players were taken indoors during the session.

Statistical analyses

Descriptive data are presented as mean ± standard deviation (SD), 95% confidence intervals and range and include both absolute and relative to time measures. Comparisons between training and game data were made using a paired sample t test or non-parametric Wilcoxon matched-pairs signed rank test for data that violated the assumptions of normality and homogeneity of variance. Cohen's *d* effect size (Cohen, 1988) and percent difference (difference between game and training divided by the mean, expressed as a percentage) were also calculated to assess the magnitude of the difference between game and training events. Differences based on effect size are referred to descriptively as very large ($4.0 > d \geq \pm 2.0$), large ($\pm 2.0 > d \geq \pm 01.2$), moderate ($\pm 1.2 > d \geq \pm 0.6$), small ($\pm 0.6 > d \geq \pm 0.2$) and trivial ($\pm 0.2 > d \geq 0.0$) (Hopkins WG, 2009). GraphPad Prism (version 6.01; GraphPad Software, La Jolla, CA, USA) was used for all statistical calculations, with significance set at $p < 0.05$.

Results

Significant differences between game and training sessions were found for all time motion analysis variables, with the exception of peak speed and total sprint distance (Table 1). The game demanded greater physical loads

Table 1. Time motion analysis data for game and training sessions. Game and training data presented as Mean ± SD with (95% confidence intervals) and [range]. Differences between game and training presented as matched-pairs comparisons (paired t-test or non-parametric Wilcoxon signed rank), effect size (Cohen's *d*)) and percent difference with (95% confidence intervals).

	Game Mean ± SD (95% CI) [Range]	Training Mean ± SD (95% CI) [Range]	Matched-pairs comparison T-test or Wilcoxon p value	Effect Size (Cohen's *d*) % difference (95% CI)
Distance – total (m)	10786 ± 2052 (9939 – 11633) [6735 – 13973]	5587 ± 1258 (5068 – 6106) [2896 – 7378]	t=12.9 (df=24) < 0.001	Very Large (3.05) 63.5% (54.3 – 72.7)
Distance - relative (m·min^{-1})	105 ± 16 (98 – 112) [68 – 134]	76 ± 14 (70 – 81) [52 – 101]	t=9.7 (df=24) < 0.001	Large (1.93) 33.0% (25.8 – 40.1)
Low speed activity - total (0-14.4 km·h^{-1}) (m)	7875 ± 1430 (7285 – 8465) [4614 – 10159]	4299 ± 901 (3927 – 4671) [2563 – 5679]	t=12.4 (df=24) < 0.001	Very Large (2.99) 58.6% (49.7 – 67.4)
Low speed activity - relative (0-14.4 km·h^{-1}) (m·min^{-1})	77 ± 10 (72 – 81) [55 – 96]	58 ± 12 (53 – 63) [41 – 84]	t=7.4 (df=24) < 0.001	Large (1.72) 28.0% (20.0 – 36.0)
High speed activity - total (> 14.4 km·h^{-1}) (m)	2911 ± 903 (2539 – 3284) [1429 – 4529]	1288 ± 484 (1088 – 1488) (117 – 2036)	t=8.9 (df=24) < 0.001	Very Large (2.24) 77.3% (60.3 – 94.2)
High speed activity - relative (> 14.4 km·h^{-1}) (m·min^{-1})	29 ± 8 (25 – 32) [13 – 45]	17 ± 6 (14 – 19) (3 – 29)	t=6.3 (df=24) < 0.001	Large (1.70) 52.2% (34.8 – 69.6)
Peak speed (km·h^{-1})	28 ± 2 (27 – 29) [25 – 31]	28 ± 2 (27 – 29) [24 – 30]	t=0.1 (df=17) 0.914	Trivial (0.04) 0.12% (-3.8 – 4.0)
Number of sprints (> 23.0 km·h^{-1})	15 ± 9 (12 – 19) [5 – 37]	9 ± 4 (7 – 11) [1 – 19]	Wilcoxon signed rank 0.001	Moderate (0.94) 43.6% (18.9 – 68.6)
Sprint time (s)	2.2 ± 0.4 (2.0 – 2.4) [1 – 3]	3.5 ± 3.1 (2.2 – 4.8) [1 - 18]	Wilcoxon signed rank < 0.001	Small (0.60) -28.9% (-46.6 – -11.2)
Sprint distance – average (m)	15 ± 3 (14 – 16) [9 – 24]	20 ± 8 (17 – 23) [7 – 43]	Wilcoxon signed rank 0.002	Moderate (0.86) -23.0% (-38.2 – -7.7)
Sprint distance – total (m)	241 ± 163 (173 – 308) [57 – 698]	174 ± 99 (133 – 215) [40 – 385]	Wilcoxon signed rank 0.134	Small (0.50) 24.1% (-6.9 – 55.1)

with large to very large differences observed for absolute and relative measures of distance, low and high speed activity. No differences were evident in peak speed, while small yet non-significant differences were recorded for total sprint distance. Small to moderate and significant differences were found for the number, duration and distance of a sprint. In contrast to the direction of other comparisons, the game resulted in shorter sprint duration and sprint distance.

Within a game, elite junior AF players recorded an average HR of 159 beats·min^{-1} in comparison to 139 beats·min^{-1} across the duration of a training session, representing a large and significant difference (Table 2). Peak heart rate was significantly higher in the game. Moderate to very large differences were observed when data were expressed within HR zones, with the larger differences recorded in the higher intensity zones. On average, a player spent approximately 59 minutes above 80% HRmax during a game and only 20 minutes above during training.

Players subjectively rated games as having a significantly higher RPE, with large differences found between game and training sessions, and instances of maximal intensity (i.e., RPE = 10) only evident in the game (Table 3). Large and significant differences in Session-RPE were also observed.

Discussion

Comparative profiles of the game and training demands are limited in adolescent team sports (Hartwig et al., 2008; 2011; Montgomery et al., 2010; Wrigley et al., 2012). Specific to elite junior AF, recommendations from previous research have stated that a more comprehensive profile of playing habits was required (Finch et al., 2002). 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) and internal (HR, Session-RPE) load parameters, compared to the in-season training environment.

Table 2. **Heart rate data for game and training sessions. Game and training data presented as Mean ± SD with (95% confidence intervals) and [range]. Differences between game and training presented as matched-pairs comparisons (paired t-test or non-parametric Wilcoxon signed rank), effect size (Cohen's *d*) and percent difference with (95% confidence intervals).**

	Game Mean ± SD (95% CI) [Range]	Training Mean ± SD (95% CI) [Range]	Matched-pairs comparison T-test or Wilcoxon p value	Effect Size (Cohen's *d*) % difference (95% CI)
HR mean (beats·min^{-1})	159 ± 10 (154 – 164) [143 – 176]	138 ± 10 (134 – 143) [119 – 158]	t=7.9 (df=19) < 0.001	Large (1.83) 14.3% (10.5 – 18.1)
HR peak (beats·min^{-1})	195 ± 10 (189 – 200) [178 – 210]	190 ± 10 (186 – 195) [174 – 210]	t=3.7 (df=19) 0.020	Small (0.47) 4.9% (1.7 – 8.1)
Time in zone (min) 50-80% HRmax	37 ± 15 (31 – 44) [19 – 81]	51 ± 20 (42 – 60) [13 – 82]	Wilcoxon signed rank 0.013	Moderate (0.75) -29.9% (-51.5 – -8.3)
Time in zone (min) > 80% HRmax	59 ± 17 (51 – 67) [34 – 96]	20 ± 9 (16 – 24) [5 - 40]	t=12.2 (df=19) < 0.001	Very Large (2.65) 103.7% (89.9 – 117.6)
Time in zone (min) > 90% HRmax	26 ± 17 (18 – 34) [1 – 61]	6 ± 4 (4 – 8) [0 - 18]	t=12.2 (df=19) < 0.001	Large (1.59) 116.6% (87.7 – 145.6)

Large to very large differences were observed in distance, low and high speed activity, mean HR, minutes spent above 80% and 90% of predicted HRmax, RPE and Session-RPE. The greater physical demands observed in competition are in line with previous findings within elite senior AF (Dawson et al., 2004) and elite junior rugby union (Hartwig et al., 2008). In elite senior AF, coaching and fitness staff generally view the game as the most physically demanding session of the weekly cycle (Gastin et al., 2013b; Rogalski et al., 2013). 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 lower in volume as the players prepare for the game (Gastin et al., 2013b).

The mean duration of a game (103 ± 12 min) was longer compared to training (78 ± 26 min). In comparison to elite AF, the game was similar while training was longer, with game durations of 99 – 104 min (position dependent) and training durations of 47 – 66 min previously reported in the literature for elite senior AF (Dawson et al., 2004; Wisbey et al., 2010). Training frequency is generally lower in junior elite AF programs (e.g., two main football training sessions scheduled in the middle of the week), with drills and sessions often having a multi-focus (e.g., conditioning, technical, tactical and competitive elements) during training and therefore being longer in duration to accommodate these objectives. Training duration for the elite junior AF cohort in the present study was broader in its range (40 – 126 min) when compared to adolescent rugby union players with a reported training duration of 58 – 93 min, depending on squad level (Hartwig et al., 2008).

Games within the TAC Cup typically saw a greater total distance covered by the player compared to training (10.9 ± 2.2 v 6.0 ± 1.6 km). Total distances within the game are in line with previous observations in the TAC Cup of between 9.2 and 11.9 km (Veale et al., 2007), although are somewhat lower than reports of 12.9 km in elite AF (Coutts et al., 2010) and reflect the known gap between under 18 and senior competition (Burgess et al., 2012). Various factors can influence external physical activity patterns within a game including match duration, fitness capabilities, motivation, chance of obtaining possession, playing position and the game plan of both teams (Brewer et al., 2010; Di Salvo et al., 2009; Pyne et al., 2005). The larger high speed activity and distance per

Table 3. **Rating of perceived exertion (RPE) and Session-RPE data for game and training sessions. Game and training data presented as Mean ± SD with (95% confidence intervals) and [range]. Differences between game and training presented as matched-pairs comparisons (paired t-test), effect size (Cohen's *d*) and percent difference with (95% confidence intervals).**

	Game Mean ± SD (95% CI) [Range]	Training Mean ± SD (95% CI) [Range]	Matched-pairs comparison T-test p value	Effect Size (Cohen's *d*) % difference (95% CI)
RPE (au)	7.8 ± 1.3 (7.3 – 8.4) [5 – 10]	5.8 ± 1.4 (5.2 – 6.4) [3 – 8]	t=5.6 (df=22) < 0.001	Large (1.48) 30.2% (19.1 – 41.4)
Duration (min)	103 ± 12 (98 – 108) [63 – 119]	78 ± 26 (67 – 88) [40 – 126]	t=5.6 (df=24) < 0.001	Large (1.23) 31.4% (17.4 – 45.4)
Session-RPE (au)	823 ± 260 (713 – 933) [210 – 1200]	515 ± 241 (411 – 620) [120 - 960]	t=4.7 (df=22) < 0.001	Large (1.22) 48.1% (22.1 – 74.1)

au = arbitrary units

minute values in games highlight the greater movement demands and intensity of work undertaken in games by players in comparison to training. Similar findings investigating the differences between game and training sessions have been reported in adolescent rugby union for total distance, low intensity activity and high intensity running (Hartwig et al., 2011). The majority of distance covered by players in the game and in training was categorised as low speed activity, a finding confirmed by a review of the physiological demands of elite AF (Gray and Jenkins, 2010).

Peak speed values for the game and training (28 ± 2 km·h^{-1}) showed no difference overall, indicating that at times, efforts within training match the efforts required to be performed within games. These speeds are comparable to those of under 18 soccer players from an elite soccer academy during international club competition (Buchheit et al., 2010). There was a noticeable difference in the number of sprints performed by players in games (15 ± 9) compared to training (9 ± 4). Sprints within games, however, were generally shorter in duration and distance. A possible explanation for this is that training is more structured over larger parts of the ground and often not restricted by positional and tactical aspects that occur within a game (Dawson et al., 2004). The data suggests that certain training drills prescribed by the coaching staff provide an equivalent speed stimulus but the overall volume of this stimulus is less than in a game (i.e., fewer number of sprints, less overall sprint distance). Future research is required to determine whether this training stimulus is sufficient and / or meets the expectations of the program and coaching staff.

An important application of HR monitoring is to evaluate the intensity of the exercise performed. It was found that players were under greater internal strain during a game, with a mean HR of 159 (± 10) beats·min^{-1} being reported for games in comparison to 139 (± 12) beats·min^{-1} for training. Similar findings were shown in the peak HR values. These findings are consistent with those of basketball (Montgomery et al., 2010) and soccer (Wrigley et al., 2012) where higher peak and average HR values were obtained during competitive match play. While competition might be expected to be performed at a higher intensity, from a conditioning perspective the duration to which players are exposed to intense work during training is an important consideration. Players spent an average of only 20 minutes working above 80% of their predicted HRmax during training (and only 6 minutes above 90%), compared to 59 minutes (and 26 minutes) during games. This training stimulus may not be long enough to maintain or improve game specific fitness, however the question warrants further and more detailed investigation. In elite AF, Dawson and colleagues (Dawson et al., 2004) recommended a decade ago that some improvements in training practices be made, having found that while game movement patterns were generally well replicated, the time between high intensity efforts was generally longer at training and that many common game activities were not practiced. The results of the present study suggest that training practices in elite junior AF might also be reviewed (e.g., training organisation and structure, prescription of load) in an effort to increase training intensity and / or time spent at higher work rates. Notwithstanding this, it is acknowledged that training typically needs to incorporate time at lower intensities to promote learning of technical and tactical skills and provide instruction. As such, training is unlikely to match the overall physical demands of competition, although selected training drills should look to replicate game movement patterns and intensities.

Conclusion

This investigation provides an improved understanding of monitoring and quantifying physical load in elite junior AF including the differences and type of movement and physiological demands players are exposed to during both game and training sessions. The information obtained from external (GPS) and internal (HR, RPE) methods of monitoring physical load can collectively assist in the facilitation of best practice advice for player management, training and weekly physical load prescription. Finally, such data can aid in the development of specific training and conditioning programs across all phases of the annual plan for the elite junior AF player. 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 movement and physiological demands of games, which can enhance training drill prescription and specificity in relation to game demands. While training should not be expected to fully replicate competition, the observed differences suggest that monitoring of physical load in both environments is warranted to allow comparisons and evaluate whether training objectives are being met.

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Key points

- Physical loads, including intensity, are typically lower in training compared to competition in junior elite Australian football.
- Monitoring of player loads in team sports should include both internal and external measures.
- Selected training drills should look to replicate game intensities, however training is unlikely to match the overall physical demands of competition.

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