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ABSTRACT

Season long competition schedules in football create unique challenges for coaches in balancing the requirements of recovery, developing and maintaining physical fitness, and adjusting the training load prior to each match. The aim of this study was to investigate the influence of player characteristics (physical fitness, age, and playing experience) and weekly training load on elite match performance across an Australian football season.

Twenty-five players from one elite team participated in this study. Prior to the season, player's age, experience, height and weight along with measures of aerobic (6 min run) and anaerobic (6 x 40 m repeated sprints) physical fitness were recorded. Individual player training load during the season was measured using GPS technology for the main training session of the week. Player match performance was calculated weekly from 33 individual playing statistics. Hierarchical linear modelling was used to investigate the relationship between match performance and weekly training load and to explore the influence of player characteristics on this relationship.

Playing experience (p < 0.01) and aerobic fitness (p < 0.05) displayed positive relationships with performance while player age (p < 0.01) showed a negative relationship. Most players coped well with weekly variations in training load; however the relationship was moderated by the results of the pre-season repeated sprint test (p < 0.05). The adverse effect on playing performance in selected players following a more intense training session suggests that recovery from the session may be delayed in players who exhibit a better anaerobic fitness profile.

Key words: periodisation; aerobic fitness; repeated sprints; GPS; playing statistics;
INTRODUCTION

Season long competition schedules in team sports such as in the football codes create unique challenges for coaches in balancing the requirements of recovery, developing and maintaining physical fitness and skill, and adjusting the training load prior to each match. The prescribed training load is typically influenced by the periodised plan along with weekly variations in schedule and performance. Increasing levels of fatigue within a week or losing fitness over the season both have potential detrimental effects on performance. While it is assumed that varying the training stimulus at regular intervals will prevent plateaus in training responses (13) and that undulating non-linear periodisation models are typically preferred in-season (27), current understanding of the serial link between weekly variations in training load and playing performance in team sports remains limited.

The literature suggests that player characteristics, such as anthropometry, physical fitness and playing experience, may influence success in soccer (6, 7, 15) and Australian football (16, 19, 22, 26, 29, 30), although most studies have focussed on the effect of these variables on team selection (16, 26, 29, 30), the likelihood of being drafted (22) and match running performance (6, 7) rather than match performance per se. Mooney et al (19) have recently demonstrated a relationship between the yo-yo intermittent recovery test (level 2), and the number of ball disposals in elite Australian football, with the relationship being mediated by the level of high intensity running within the match and by playing experience. In contrast, similar relationships were not found with player impact scores and coach performance ratings, considered more appropriate measures of performance than disposals alone (14).

As such, the purpose of this study was to investigate the relationship between physical fitness, age and experience on match performance in elite Australian football, and to explore possible
links between weekly training load and match performance. We hypothesised that physical
fitness and playing experience would be positively related to match performance, while
planned variations in the weekly periodised training load would have little effect.

METHODS

Experimental Approach to the Problem

This prospective study investigated the influence of physical fitness, age, playing experience
and weekly training load on match performance over an entire season in elite Australian
football. Playing experience (number of matches played) and age (years) were recorded on
the 1st of January 2008, as listed in the Australian Football League (AFL) Record (18).

Measures of aerobic and anaerobic running fitness were taken at the end of the pre-season
when at peak level (12). Measures of individual player training load and match performance
were recorded weekly throughout the season.

Participants

Twenty-five players from one elite AFL team, all of whom played at least one senior match
during the 2008 season, were recruited for this study. The Deakin University Human Research
Ethics Committee approved the study and written consent was obtained from all players.

Procedures

Aerobic fitness was measured in the field using a 6 min continuous run for maximal distance.
The total distance run was used as an indication of aerobic power, based on the concept of
velocity at maximal oxygen uptake (VO_{2\text{max}}) and the time limit to exhaustion (4), with 6 min
equivalent to a work intensity of approximately 105% VO_{2\text{max}} and time spent at VO_{2\text{max}}
around 4 min (3). The well maintained grass oval had a running track measured to 400 m
using a calibrated trundle wheel, with markers placed every 20 m to ensure that the total
distance was accurately recorded. As such, the test had a maximal error of ± 10 m. The
typical error for this test in this playing group, expressed as a coefficient of variation, was
1.6% (n = 31).

A modified repeated sprint test was used as a measure of anaerobic high intensity running
fitness (25). Players completed a set of six 40 m sprints, beginning every 15 s through a
system of timing gates (Swift Technology, Lismore, N.S.W) set up to allow out and back
return efforts. The time for the first 40 m sprint was taken as a measure of the player’s
maximum speed. Total time and fatigue index were determined from the six 40 m sprints,
disregarding recovery time between sprints. Fatigue index was calculated using the two
equations suggested by Zagatto et al. (31). The typical error for this test in this playing group,
expressed as a coefficient of variation, was 1.8% for 40 m sprint time and 1.6% for total time
for six 40 m sprints (n = 24).

Training load was measured using GPS technology (SPI Elite unit, GPSports, Fyshwick,
A.C.T.) during the main football training session each week. This session was typically used
to vary the training load in the periodised training plan, with other sessions earlier and later in
the week more consistent in load and designed to focus on recovery from the match and
technical and tactical aspects leading in to the match. The GPS unit was worn in a harness
located between the player’s shoulder blades and sampled at a rate of 1 Hz. The SPI Elite
GPS device has been shown to provide accurate (≤ 4%) and reliable data for total distance
travelled during team sport movement patterns (9). After each training session, data were
downloaded from the units using the associated Team AMS software package (Ver. 1.2.1.12,
GPSports, Fyshwick, A.C.T.).
The speed exertion variable was chosen from the software as the best single descriptive measure of training load. The use of an exertion index based on GPS time-motion data has previously been described in Australian football, although the algorithms used by Wisbey et al (28) were developed by the authors rather than those available within the manufacturer’s software. In our study, speed exertion (measured in arbitrary units, au) was derived from linear algorithms based on time spent in six different speed zones. These speed zones were individualized for each player according to their maximum speed, as measured from the first sprint of the repeated sprint test, and ranged from 10% to 110% of a player’s maximum speed. The six speed zones were linearly weighted from 1 to 6, similar to methods used to quantify load using heart rate technology (1, 11), so that faster speed zones had a higher weighting. Therefore, a player who spent a greater proportion of time in higher speed zones would have a higher speed exertion compared to a player who spent less time in these zones.

Performance Measures

Individual match performance was measured using an impact rating system similar to those previously described in Australian football (14, 19, 24). The impact score quantified individual playing performance from 33 match statistics that incorporated all aspects of play (i.e. offensive, defensive and stoppages) as collected by two AFL approved companies (Champion Data, Victoria: http://www.championdata.com.au/; ProWess Sports, Victoria: http://prowess.com.au/). Champion Data provide a 99% accuracy for match statistics (20). These statistics were weighted for importance using a confidential formula developed by the coaching staff and agreed to at the beginning of the season. The impact score was measured in arbitrary units.
Statistical Analyses

All variables were analysed using a multi-level linear model (HLM Ver. 6, Scientific Software International Inc., Lincolnwood, Illinois) (23). This analysis allowed for repeated measures of training load and performance (level 1 predictors) to be modelled against each other while accounting for differences in player characteristics (level 2 predictors) of player age, playing experience, aerobic and anaerobic running fitness. As such a predictive equation for match performance was produced showing the impact each variable had on match performance after all other independent variables had been accounted for. The independent variables were all centred before being added to the model. Level 1 predictors were player centred (i.e. each player’s mean was subtracted initially for all individual data points) and level 2 predictors were grand mean centred (i.e. the group mean was subtracted initially for all individual data points). This is an important procedure as it reduces the impact of multi-collinearity (for example the correlation between age and experience was very high). All data are presented as mean ± SD and range with significance of coefficients set at p < 0.05.

RESULTS

Data are presented for 25 players (age: 24.1 ± 3.0 y; height: 188.3 ± 7.3 cm; weight: 90.4 ± 8.3 kg) across the 22 weeks (i.e. matches) of the 2008 AFL season. A total of 310 paired training load and match performance samples were analysed. The weekly relationship between training load and match performance throughout the season, including the variability in the data, is illustrated in Figure 1. Bivariate analysis indicated that age – playing experience and 40 m sprint – 40 m repeated sprints were highly correlated (Table 1). Sprint and repeated sprint performance significantly declined with age and playing experience. Level of fatigue in the repeated sprint test decreased with improving aerobic fitness and increased with improving player 40 m speed.
Descriptive statistics for pre-season player characteristics and in-season training load and match performance measures, along with the output of the multi-level linear model for significant predictors are provided in Table 2. The coefficients from the modelling can be used to create a linear algorithm to predict performance:

\[
\text{Match Performance (au)} = 101.61 - 12.66(\text{Age-24.12}) + 0.72(\text{Experience-84.12}) + 0.14(6 \text{ min run-1658}) + 0.74(\text{Week-player mean}) + (0.0056+0.0082*(\text{Six 40m sprints-35.56}))(\text{Training load-player mean})
\]

Training load and week number had very little impact on match performance with only 3.2% of the variability (i.e. $r^2$) in the data being explained by these two variables. Individual player characteristics, however, had a significant impact accounting for 45.3% of the total variability in the match performance data. Player’s age (negative impact), playing experience (positive impact) and pre-season aerobic fitness (positive impact) were observed to have significant coefficients when predicting match performance. Week number was also significant in the model, indicating improvements in match performance across the season. Variables from the repeated sprint test had no significant influence on the prediction of match performance, although the coefficient of training load was influenced by the speed at which the players completed the six 40 m sprints (Table 2, Figure 2). That is, as training load (i.e. speed exertion) increased above the mean (2051 au), corresponding match performance in players with good repeated sprint ability decreased. Conversely players with poor repeated sprint
ability (i.e. slowest total time) and those close to the mean of the group coped well and showed improved performance.

**DISCUSSION**

The aim of the present study was to investigate the influence of player characteristics (physical fitness, age, and playing experience) and weekly training load on elite match performance across an Australian football season. The analysis calculated the influence each variable had on match performance, while controlling for the influence of all other variables. Playing experience and aerobic fitness were found to have a significant positive effect on match performance, while player age had a significant negative effect. The relationship between training load and match performance was influenced by a player’s total time for six 40 m sprints, such that variations in training load were tolerated in different ways depending on a player’s repeated sprint ability.

An important focus of this study was the influence of weekly training load on associated weekly match performance. Variability within the data is clearly evident, both at an individual level (depicted by the SD bars in Figure 1) and at a team level from week to week (i.e. the mean for each week). The team coped well with weekly variations in training load with less than a 10% variability in match performance associated with the lightest and heaviest main training session for the week (see the mean data in Figure 2). The recommendations in the periodisation literature that undulating non-linear loading models are typically preferred in-season (27) and that varying the training stimulus prevents plateaus in training responses seem justified.
However the modelling for training load indicates that performance on the repeated sprint test moderates the relationship suggesting that slower players are able to tolerate higher training loads better than their faster counterparts. This may be due to individual differences in the degree of muscle damage associated with a heavy training session along with the speed of recovery. Muscle damage is influenced by a variety of factors including exercise intensity, the number and velocity of contractions during exercise, work performed, exercised muscle length and individual differences in fibre type composition and muscle architecture (8, 21).

Players with enhanced anaerobic running profiles may reach faster speeds in training and experience greater eccentric loading while decelerating (17). The recovery from fast velocity eccentric exercise has been shown to be considerably longer compared to slow velocity exercise, despite muscle soreness being similar in severity (21). For the players who performed less well on the repeated sprint test, improved match performances associated with higher training loads may also be reflective of increases in high intensity running fitness as the season progressed.

When it comes to selection in a senior elite team, it is likely that players with the most experience will be chosen. For example, Young et al (30) found that from a squad of 34 players who were tested during pre-season at one elite AFL club, the 22 players that started the season playing in the senior side were significantly older and more experienced than the non-starters. In the present study, however, we were interested in individual match performances over an entire season. In this situation, age and playing experience are confounding variables as playing experience can only ever increase with advancing age. The analysis approach employed allowed each of these variables to be controlled. In doing so it was found that playing experience was positively related to match performance while age was negatively related. This suggests that at one end of the continuum, older players may
compensate for declining physical abilities with greater experience (e.g. enhanced tactical and competitive skills (19)), while younger players may compensate for a lack of experience with greater athleticism. Mean age in the current study (24.1 y) was similar to the starting group in the Young et al (30) study (24.0 y), while playing experience was 84 and 90 matches, respectively. These likely represent typical means across the competition, however from a list management perspective, our findings suggest that exposing young players to more elite matches early in their career may help to prolong a higher performance output for a club over a longer period of time.

The data available to assess fitness characteristics and individual match performance in football is limited, although proxies for performance such as selection (16, 26, 29, 30) and running parameters within a match (6, 7) have been used. The present study indicated that aerobic fitness, measured as a continuous run for distance over 6 min, significantly influenced match performance in our sample of 25 players and 310 matches. Aerobic endurance training has been shown to significantly improve performance in elite junior soccer by increasing running performance, work intensity and the number of involvements with the ball during a match (15). Mooney et al (19) found a positive relationship between the yo-yo intermittent recovery test (level 2) and ball disposals in elite Australian football yet failed to demonstrate similar relationships with coach performance ratings and player impact scores similar to those used in the present study. The limited sample size (9 players) and number of individual performances (21 matches) may help explain these inconsistencies, although performance on the yo-yo intermittent recovery test would be expected to correlate well with match performance given it is a test designed to match the running demands of field team sports and is influenced by a variety of physiological determinants (2).
An unexpected finding in the present study was the lack of influence of maximal speed and repeated sprint ability on match performance. The repeated sprint protocol was modified to place considerable stress on anaerobic metabolism and limit recovery (i.e. a 40 m sprint completed every 15 s) while still meeting recommendations for repeated sprint testing in field team sports (25). Given the frequency of sprinting in elite Australian football and the perceived importance of high intensity running distance during a match (10, 28) it was thought that repeated sprint ability would influence player match performance. For example, high intensity running distance is known to be a more discriminating variable compared to total running distance when describing differences between elite and sub-elite players in Australian football (5). While further investigation is warranted, one possible explanation for our results relates to the homogeneity of the data, with the range in scores for the sprint and repeated sprints being considerably less than for the 6 min run, such that the similarity in performance in these tests across the playing group may mask potential differences that could otherwise be evident in a more heterogeneous group.

This study highlights the influence and the complex interaction of player characteristics and program variables that must be considered when training an elite Australian football squad for competition. It reinforces the importance of having a training program individualized to account for differences in player characteristics within the team environment. Factors such as player age, playing experience, physical fitness qualities and training load may all impact upon individual player match performance.

**PRACTICAL APPLICATIONS**

Varying the weekly training load in field team sports, as is recommended in the literature, would seem justified from a team perspective, however individuals within the team may
respond differently depending on personal characteristics. Our data suggests that players with
good anaerobic running profiles, as evidenced by performance on a repeated sprint test,
appear less equipped to cope with a heavy training load leading into a match than their slower
team-mates. Care must therefore be taken with the extent of the load, the need to expose all
players to the same load or the recovery time and practices provided prior to a match.

The opposing influence of player age and playing experience on match performance has
implications for player list management in elite Australian football. Providing opportunities
for young players to be exposed to elite competition earlier in their career may ensure a longer
period of sustained performance in the years when optimal physical capacity and playing
experience overlap (e.g. players in their mid-20's who are well experienced, have a good
training history and remain physically capable of performing and coping with a highly
demanding game).

Even at the elite level, small gains in aerobic fitness may result in match performance gains.
The importance of running fitness cannot be underestimated in a sport that demands mean
total distances of approximately 13 km, high intensity running distances (> 14.4 km h\(^{-1}\))
nearing 4 km, and 28 efforts above 23 km h\(^{-1}\) per match (10). Failure in our data to show
similar influences on match performance with speed and repeated sprint ability was
unexpected and may be more related to the lack of homogeneity (i.e. variability) in the data in
this group of players than the importance of these running parameters.
REFERENCES


FIGURE LEGENDS

Figure 1: Weekly training load and associated match performance throughout a regular season of elite Australian football (n = 25 players). Training load in the main training session of the week was derived from GPS measures and summarised as a single variable (speed exertion) in the manufacturer's software (Team AMS, GPSports, ACT, Australia). Performance was derived from 33 individual player match statistics involving all aspects of play (i.e. offensive, defensive, stoppages) and weighted for importance by the coaching staff. au = arbitrary units

Figure 2: Illustrated example of the multi-level linear model describing the influence of training load and match performance. Data is shown in relation to the lightest, mean and heaviest training loads recorded during the season. Mean data is shown for the squad along with examples corresponding to the fastest and slowest times recorded for the repeated sprint test, which significantly (p = 0.23) moderated the relationship between training load and match performance.
Table 1.

Bivariate relationships between player variables.

<table>
<thead>
<tr>
<th>Age</th>
<th>Playing experience</th>
<th>6 min run distance</th>
<th>40m sprint</th>
<th>6*40m sprint</th>
<th>Fatigue Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Playing experience</td>
<td>0.90**</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 min run</td>
<td>-0.27</td>
<td>-0.27</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40m sprint</td>
<td>0.40*</td>
<td>0.44*</td>
<td>-0.06</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>6*40m sprints</td>
<td>0.35</td>
<td>0.41*</td>
<td>-0.30</td>
<td>0.71**</td>
<td>1.00</td>
</tr>
<tr>
<td>Fatigue index</td>
<td>-0.22</td>
<td>-0.27</td>
<td>-0.49**</td>
<td>-0.56**</td>
<td>0.00</td>
</tr>
</tbody>
</table>

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).
Table 2.

Descriptive statistics for the independent variable (match performance) and level 1 and level 2 predictors, along with the output for significant predictors from the multi-level linear model analysis.

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Coefficient</th>
<th>Significance (P-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Match performance† (au)</td>
<td>310</td>
<td>108.5</td>
<td>48.9</td>
<td>19</td>
<td>309</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Level 1 predictors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Week number</td>
<td>310</td>
<td>11.1</td>
<td>6.3</td>
<td>1</td>
<td>22</td>
<td>0.74</td>
<td>0.027</td>
</tr>
<tr>
<td>Training load (au)</td>
<td>310</td>
<td>2051.0</td>
<td>503.4</td>
<td>291</td>
<td>4032</td>
<td>(0.0056 + (0.0082*Six 40m)</td>
<td>0.023</td>
</tr>
<tr>
<td><strong>Level 2 predictors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (y)</td>
<td>25</td>
<td>24.1</td>
<td>3.0</td>
<td>19</td>
<td>30</td>
<td>-12.66</td>
<td>0.005</td>
</tr>
<tr>
<td>Playing experience (matches)</td>
<td>25</td>
<td>84.1</td>
<td>63.0</td>
<td>0</td>
<td>213</td>
<td>0.72</td>
<td>0.001</td>
</tr>
<tr>
<td>6 min run (m)</td>
<td>25</td>
<td>1658.4</td>
<td>76.6</td>
<td>1480</td>
<td>1800</td>
<td>0.14</td>
<td>0.044</td>
</tr>
<tr>
<td>40 m sprint (s)</td>
<td>25</td>
<td>5.41</td>
<td>0.16</td>
<td>5.10</td>
<td>5.69</td>
<td>--</td>
<td>NS</td>
</tr>
<tr>
<td>6*40 m sprints (s)</td>
<td>25</td>
<td>35.56</td>
<td>0.91</td>
<td>33.71</td>
<td>37.33</td>
<td>--</td>
<td>NS</td>
</tr>
<tr>
<td>Fatigue index (au)</td>
<td>25</td>
<td>10.07</td>
<td>2.52</td>
<td>6.22</td>
<td>15.67</td>
<td>--</td>
<td>NS</td>
</tr>
</tbody>
</table>

au = arbitrary units; Six 40 m = total time for six 40 m repeated sprints; N/A: Not applicable as match performance was the dependent variable;

NS = not significant, therefore not included in the final model

† The constant term in the model in the prediction of match performance = 101.61 au
Figure 2