Relationship between pre-season training load and in-season availability in elite Australian Football players

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ABSTRACT

Objectives**:** Investigate the relationship between the proportion of pre-season training sessions completed, and load and injury during the ensuing Australian Football League season.
Design: Single cohort, observational study.
Methods: Forty-six elite male Australian football players from one club participated in this study. Players were divided into three equal groups based on the amount of pre-season training completed (high, HTL, >85% sessions completed; medium, MTL, 50-85% sessions completed, and low, LTL, <50% sessions completed). Global Positioning System (GPS) technology was used to record training and game loads, with all injuries recorded and classified by club medical staff. Differences between groups were analysed using a two-way (group x training/competition phase) repeated measures ANOVA, along with magnitude-based inferences. Injury incidence was expressed as injuries per 1,000 hours.
Results: The HTL and MTL group completed a greater proportion of in-season training sessions (81.1% and 74.2%) and matches (76.7% and 76.1%) than the LTL (56.9% and 52.7%) group. Total distance and Player load were significantly greater during the first half of the in-season period for the HTL ($p=0.03$, ES=0.88) and MTL ($p=0.02$, ES=0.93) groups than the LTL group. The relative risk of injury for the LTL group (26.8/1,000 hours) was 1.9 times greater than the HTL group (14.2/1,000 hours) ($\chi^2=3.48$, df=2, $p=0.17$).
Conclusions: Completing a greater proportion of pre-season training resulted in higher training loads and greater participation in training and competition during the competitive phase of the season.

Introduction

During Australian football (AF) match-play, players are required to perform repeated high-speed (i.e. sprinting, running) efforts and physical contacts, interspersed with low-speed (i.e. jogging, walking) movements.[1,2] In order to reach and maintain the required level of physical activity throughout a match, strength and conditioning staff are required to prescribe adequate training loads to enhance physical qualities, while also minimizing the negative responses to training (e.g. fatigue, illness, and injury).[3,4] As previously suggested,[5] an inadequate training stimulus will fail to elicit the required physiological adaptation, while an excessive training stimulus, with inadequate recovery periods may increase the risk of injury or illness.

During the competitive season, it is difficult to prescribe a training stimulus sufficient to enhance fitness, as time to allow recovery between matches is required.[6] Accordingly, the pre-season period is seen as a crucial period to develop physical qualities to meet the required level of physical demands during match-play.[4] Previously, training loads during the pre-season period have been reported as 2–4 times greater than during the in-season period,[7,8] and consequently the accurate control of training loads during this period is essential to both maximize positive training adaptations, and minimize the negative training response.[7-9] The relationship between training load and incidence of injury and illness over a pre-season period has been analyzed, with Piggott et al.[10] reporting no significant relationships between injuries or illness and training load across this period. However these findings should be interpreted with some caution due to the small number of injuries (n = 5) and study duration (a 15-week pre-season). Further research and larger studies are required to provide a more comprehensive understanding of the relationship between load and injury during the pre-season period, and the ensuing in-season period, including early season and late season.

The physical demands of AF have increased over the last decade,[11] and soft tissue injuries remain the most common injury in the game.[12] Previously, it has been shown that high training loads, or inadequate recovery periods can increase the risk of soft tissue injury in elite team sport athletes.[13,14] As such, an increased emphasis has been placed on quantifying loads during training and competition, to determine the relationship between load and injury.[13,15,16] Specifically, in sub-elite rugby league players, increases in session-RPE training load have been associated with increases in the likelihood of injury.[5] In addition, recent work by Rogalski et al.[15] in AF showed that larger 1-weekly (>1750 arbitrary units, OR = 2.44 – 3.38), 2-weekly (>4000 arbitrary units, OR = 4.74), and previous-to-current week changes in load (>1250 arbitrary units, OR = 2.58) were significantly related to an increased injury risk during the in-season period. Similarly, during a pre-season training block, greater 3-weekly distance covered (OR = 5.49, p = 0.008) and 3-weekly sprint distance (OR = 3.67, p = 0.074) were associated with a higher non-contact soft tissue injury risk during the pre-season period.[16]

Recent investigations into the relationship between load and injury, and load and performance have investigated the acute:chronic load ratio, i.e. the load performed in 1 week (acute load) relative to the average of the previous four weeks (chronic load).[17-19] Specifically, in elite cricket fast bowlers, it has been shown that high loads over a chronic period (i.e. 4-weeks) results in positive physiological adaptations that potentially minimize the fatigue response, and in turn reduce the likelihood of injury.[17] Similarly, Hulin et al[18] reported that elite rugby league players with a high chronic load, compared to those with a low chronic load, were more resistant to injury when acute load was similar to chronic load (i.e. acute:chronic load ratio ~0.8-1.3).[18] Collectively, these findings suggest that high chronic loads, coupled with moderate acute:chronic load ratios may provide a protective effect against injury.[17-19]

Recent work from elite rugby league has shown that players who completed a greater proportion of the planned pre-season experienced a lower incidence and severity of injuries during the competitive phase of the season.[20] While studies have explored the relationship between load and injury in elite AF players, there is limited research that has investigated the relationship between the proportion of pre-season training sessions completed, and subsequent training and match loads and injury risk in the ensuing season. Therefore, it was the aim of the present study to investigate the relationship between the proportion of pre-season training completed and subsequent in-season load, match availability, and injury risk in the ensuing season in elite Australian football players.

Methods

Subjects

Forty-six elite Australian football players from one professional Australian Football League (AFL) club (mean ± SD age, 23.1 ± 3.7 years; height, 189.2 ± 7.1 cm; mass, 87.0 ± 8.2 kg) participated in this study. All participants received a clear explanation of the study, including information on the risks and benefits of participation. The Australian Catholic University Human Research Ethics Committee approved all experimental procedures (Approval Number 182E).

Training and Competition Loads

Participants were fitted with a 10 Hz GPS (Global Positioning System) unit (Optimeye S5, Catapult Innovations, Melbourne, Victoria, Australia) during data collection. The GPS unit also housed a tri-axial accelerometer, gyroscope, and magnetometer sampling at 100 Hz to provide information on the movement demands during training and competition. Participants were equally divided into thirds and assigned to a high (HTL, completed > 85% of pre-season sessions, n = 15), medium (MTL, completed 50-84.9% of pre-season sessions, n = 16), or low (LTL, completed <50% of pre-season sessions, n = 15) training load group at the beginning of the competitive season based on the percentage of main pre-season sessions completed. The characteristics of players in each group were as follows; HTL group (mean ± SD age, 22.8 ± 2.9 years; playing experience, 3.9 ± 2.6 years; percentage of pre-season spent in rehabilitation group, 4.6 ± 4.3 %), MTL group (mean ± SD age, 23.3 ± 3.8 years; playing experience, 5.0 ± 3.5 years; percentage of pre-season spent in rehabilitation group, 21.8 ± 11.5 %), LTL group (mean ± SD age, 22.8 ± 4.2 years; playing experience, 4.7 ± 4.3 years; percentage of pre-season spent in rehabilitation group, 46.0 ± 33.5 %). While it would have been ideal for all players to complete all training sessions, on occasions, players were required to undertake modified training activities in order to minimize excessive fatigue and injury risk. The types of training sessions were main training sessions, modified training sessions, and rehabilitation training sessions. Main training sessions reflected completion of the total prescribed sessions comprised of running and speed along with skills; modified training sessions reflected partial completion of prescribed sessions; and rehabilitation sessions reflected completion of an individualized injury-specific return-to-play program.

Training and match loads were categorized cumulatively into the following variables; (1) total distance (TD, m), (2) low-speed distance (LSD, 0.00–6.00 km.hr^{-1}), (3) moderate-speed distance (MSD, 6.01–18.00 km.hr^{-1}), (4) high-speed distance (HSD, 18.01–24.00 km.hr^{-1}), (5) very high-speed distance (VHSD, >24.00 km.hr^{-1}), and (6) player load (PL, au). This technology has demonstrated adequate validity and reliability for accurate measurement of velocity, distance, acceleration, and player load.[21,22] Player load was measured as a modified vector magnitude using accelerometer data from the microtechnology unit. It is expressed as the square root of the sum of the squared instantaneous rate of change in acceleration in each of the three vectors (X, Y, and Z axis) and divided by 100.[21] In addition, all injuries were classified by medical staff at the football club with injury reports maintained and updated daily throughout the season. An injury was recorded if it occurred during training or competition and resulted in a missed match.[15] Injuries were categorized according to injury type (description) and body site (location).

Statistical Analysis

Data were analyzed using SPSS 22.0 (SPSS Inc., Chicago, IL, USA), where load variables in; 1) the pre- and in-season period, and 2) the first and second half of the in-season period were compared using a two-way (load group x training/competition phase) repeated measures ANOVA. If significant main effects were found, Bonferroni post hoc analyses were used to determine the source/s of the differences. Data were checked for normality using a Shapiro-Wilk test, and a Pearson's product moment correlation coefficient was used to assess the relationships among: percentage of pre-season completed, match availability, pre-season training load, and in-season training load. Descriptors were used to describe the size of the correlation between variables, and were as follows: trivial; <0.1, small; 0.1–0.3, moderate; 0-3–0.5, large; 0.5–0.7, very large; 0.7–0.9, and nearly perfect; >0.9.[24] Given the practical nature of the study, magnitude-based statistics were used to determine any practically meaningful differences between groups.[23,24] The magnitude of the change in the dependent variables were also assessed using Cohen's effect size (ES) statistic,[25] and 90% confidence intervals (CI). Effect sizes of <0.2, 0.2–0.6, 0.61–1.2, 1.21–2.0, and >2.0 were considered trivial, small, moderate, large, and very large, respectively.[24] Likelihoods were subsequently generated and thresholds used for assigning qualitative terms to chances were as follows: <1%, almost certainly not; <5%, very unlikely; <25%, unlikely; <50%, possibly not; ≥50%, possibly; ≥75%, likely; ≥95%, very likely; ≥99%, almost certainly.[23,24] The magnitude of differences between groups was considered practically meaningful when the likelihood was ≥75%.[23,24] In addition, injury rates were also calculated for each load group (i.e. high, medium, and low). Injury incidence was calculated by dividing the total number of injuries by the overall exposure hours for each load group and expressed as rates per 1,000 hours of exposure and 95% confidence intervals (CIs). The chi squared test (χ^2) was used to determine significant differences between load groups. All data were reported as means ± SD and significance was set at p<0.05.

Results

Across the season, a total of 3,710 individual sessions were recorded. Of these, 1,765 individual training sessions were observed during the pre-season period, and 1,945 individual sessions (i.e. training and competition) were recorded during the in-season period. Collectively, training loads were ~1.3 times greater during the pre-season period than the in-season period (p=0.02). Figure 1 shows the total training duration and the proportion of session distribution across the pre- (A, B) and in-season (C, D) periods. During the pre-season period, the HTL group collectively completed 87.2% of the prescribed sessions, while the MTL and LTL groups completed 61.3% and 35.4%, respectively. Similarly, during the in-season period, the proportion of time in main training was slightly higher for the HTL group with 57.3%, compared with the MTL groups with 57.1% (p>0.05, ES=0.16 [-0.51-0.66], 52% Possibly). Further, the proportion of time in main training for both the HTL (p>0.05, ES=1.20 [0.71-1.70], 100% Almost Certainly) and the MTL (p>0.05, ES=1.01 [0.47-1.56], 99% Almost Certainly) groups were higher than the LTL (49.8%) group. Similarly, the HTL and

MTL groups were available to play for 76.7% and 76.1% of in-season competitive matches, respectively (p>0.05, ES=0.02 [-0.64-0.60], 41% Possibly). In comparison to the HTL (p>0.05, ES=0.84 [0.27-1.41], 97% Very Likely) and MTL (p>0.05, ES=0.82 [0.25-1.39], 96% Very Likely) groups, the LTL group was only available to play for 52.7% of in-season competitive matches.

Insert Figure 1 About Here

During the pre-season period, the HTL group completed greater training load for all variables than both the MTL (p<0.05, ES=1.32–1.58, 100% Almost Certainly) and LTL (p<0.05, ES=1.47–1.78, 100% Almost Certainly) groups (Table 1). Similarly, the MTL group completed greater training load for each measured variable (p<0.05, ES=1.09–1.43, 100% Almost Certainly) than the LTL group. During the competitive season, there were no statistically significant differences in TD covered between the groups, however practically meaningful differences were observed where the HTL (p=0.12, ES=0.72 [0.13–1.31], 93% Likely) and MTL (p=0.12, ES=0.73 [0.16–1.31], 94% Likely) groups covered practically greater TD than the LTL group. Moreover, the HTL group completed moderately greater VHSD (p=0.01, ES=0.80 [0.22–1.38], 96% Very Likely) and PL (p=0.12, ES=0.73 [0.14–1.31], 93% Likely) than the LTL group. The MTL group had moderately greater VHSD (p=0.01, ES=0.54 [0.05–1.14], 83% Likely), and PL (p=0.15, ES=0.70 [0.12–1.28], 92% Likely) than the LTL group. There were no differences between the HTL and MTL groups during the season.

Insert Table 1 About Here

Percentage of pre-season training completed, match availability, pre-season training load, and in-season training load are shown in Table 2. A near perfect correlation was observed between the percentage of pre-season training completed and pre-season TD (r = 0.96, p = 0.001). Further, a very large correlation was observed between the percentage of pre-season training completed and pre-season HSD (r = 0.86, p = 0.001). Similarly, a near perfect correlation was observed between in-season TD and match availability (r = 0.95, p = 0.01). There were moderate correlations observed between percentage of pre-season training completed and match availability (r = 0.31, p = 0.04), and pre-season TD (r = 0.36, p = 0.02), HSD (r = 0.34, p = 0.02), and match availability.

Insert Table 2 About Here

During the first half of the season, the HTL (p=0.03, ES=0.88 [0.31–1.44], 97% Very Likely) and MTL (p=0.02, ES=0.93 [0.38–1.47], 98% Very Likely) groups covered significantly greater weekly TD than the LTL group. Similarly, PL values were significantly higher for both the HTL (p=0.03, ES=0.89 [0.33–1.45], 98% Very Likely) and MTL (p=0.02, ES=0.93 [0.38–1.48], 98% Very Likely) groups compared to the LTL group. The HTL group completed moderately greater (albeit not significantly) MSD (p=0.32, ES=0.60 [0.00–1.19], 87% Likely) and VHSD (p=0.18, ES=0.75 [0.17–1.34], 94% Likely) than the LTL group (Figure 2). Further, there were no significant or practical differences in any load category for the LTL group from the first to the second half of the season.

Insert Figure 2 About Here

Across the in-season period, 50 injuries were recorded, with the knee (22%), hamstring (14%), and ankle (10%) the most common sites of injury. Although there was a trend toward greater injury rates in the low load group, no significant differences (χ^2=3.48, df=2, p=0.17) were found between the HTL (14.2 [95% CI, 6.92-25.50] per 1,000 hours), MTL (17.7 [95% CI, 9.90-27.22] per 1,000 hours), and LTL (26.8 [95% CI, 12.22-30.89] per 1,000 hours) groups.

Discussion

This study investigated the relationship between training load completed during the pre-season period and subsequent in-season weekly loads (i.e. training and match loads) and injury during the ensuing season in elite Australian football players. During the in-season period, the HTL group completed a greater proportion of main training sessions and matches than both the MTL and LTL groups. Similarly, there were large differences in the proportion of main training sessions completed and training load between the HTL, MTL, and LTL groups during the pre-season period. No differences between the HTL and MTL groups during the in-season were observed, however both groups were higher than the LTL group for TD, VHSD, and PL. In addition, there were moderate to large differences for TD, PL, MSD, and HSD between the HTL and MTL groups, and the LTL group during the first half of the season. Furthermore, the lowest and highest injury rates were observed for the HTL and LTL groups, respectively.

Similar to previous findings,[8,15] we found that training load was higher during the pre-season phase than the in-season phase. Further, very large to nearly perfect correlations existed among the percentage of pre-season training completed and pre-season TD and HSD. A moderate correlation existed between the proportion of pre-season training completed and match availability suggesting that factors in addition to, or other than pre-season training determine in-season match availability. However, our findings demonstrate that 1) completing a greater proportion of pre-season training sessions results in a greater pre-season training load, 2) greater pre-season training load is positively associated with a greater in-season training load, and 3) greater in-season training load is positively associated with greater match availability.

Unlike previous work, once separated into respective load groups, training load was significantly higher during the pre-season phase for both the HTL and MTL groups, but not the LTL group. This is likely due to the fact that during the pre-season period, the LTL group were unable to complete as much training as both the HTL and MTL group, respectively (Figure 1A). These findings suggest that players in both the HTL and MTL groups had greater opportunity to 1) participate in a greater proportion of training and 2) maintain a higher training load to develop the required physical qualities to compete in matches during the in-season phase.[4] Of the training the LTL group did perform, they were only able to complete 35.4% of the prescribed training sessions. In contrast, the HTL group and the MTL group completed 87.2% and 61.3% of the prescribed training sessions, respectively (Figure 1B). This may be due to a multitude of factors including but not limited to; injury, “off-legs” conditioning, increased time spent in the rehabilitation program, and individually modified training load programs. Moreover, during the in-season period, players in the HTL and MTL groups spent more time completing main training sessions, and less time completing rehabilitation sessions than players in the LTL group (Figure 1C). Similar to previous findings,[26] approximately 50% of external load was obtained through competition during the in-season period (Figure 1D). These findings have important practical applications for strength and conditioning staff involved in the preparation of athletes. Specifically, players should attempt to complete as much of the planned pre-season training program as possible in order to; 1) develop the physical qualities required to compete in competition, and 2) develop resilience to tolerate training and match loads during the season.[20]

As expected, there were significant differences among load groups for all measured load variables during the pre-season period. During the in-season there were no notable differences between the HTL and MTL groups, although both groups were higher than the LTL group for TD, VHSD, and PL. In addition, during the first half of the season we found that TD and PL were significantly greater for the HTL and MTL groups compared to the LTL group. A possible explanation for this finding is that players who were unable to complete a large amount of pre-season training (<50%) may have been underprepared for the physical demands of competition,[1,2] and therefore below the load threshold necessary to promote physiological adaptation.[4] As a consequence, their risk of injury may have increased due to an inadequate level of fitness.[4,27,28] In contrast, there were only moderate differences between both the HTL and MTL group and LTL for VHSD, with no significant differences between any groups during the second half of the season. This most likely reflects decreases in training load for the HTL and MTL groups due to an increased in-season focus on recovery between competitive matches,[8,30] as opposed to increases in training load for the LTL group. However, across the first to second half of the season, the LTL group experienced a minor increase (albeit not significant) in total load. With competition cited as the main external stimulus during an in-season weekly cycle,[26] a possible explanation for this finding is that players within the LTL group were able to use competition to increase their weekly total load during the in-season period.

Recent investigations in cricket,[17] and rugby league,[18] have demonstrated that sustained high chronic loads may offer a protective effect against injury.[19] There were no significant differences between groups for injury rates, although injury rates were nearly two-fold greater in the LTL group compared with the HTL group. While these are preliminary findings from one club in an elite Australian football competition, further research is required to understand the protective effect of sustained high chronic load in Australian football.

While this study provides some novel findings surrounding training load, there are some limitations that warrant discussion. First, it should be acknowledged that the present data is from one club and may be solely related to this particular cohort of players in this particular season. It is also possible that the results are a reflection of the training philosophies of the coaches and strength and conditioning staff of the studied club, and may not reflect the training practices of other AFL clubs. Second, it should be noted that the ability to draw strong conclusions on the relationship between load and injury may be limited due to an overall low number of injuries (n = 50). Further investigations across a larger number of players and Australian Football teams would clearly strengthen the present findings. Finally, no measures of internal load were included in this study. While GPS technology provides detailed information on the external load of players, other measures of internal training load (i.e. session-RPE, heart rate, etc.) should also be monitored to provide detailed insight into the training loads, and subsequent load-injury relationship of athletes. Including internal loads, larger injury numbers, and more players would provide a greater understanding of the relationship between load and injury.

Practical Applications

The results of the present study demonstrate that high training loads during the pre-season period allow players to develop the required physical qualities for competition, while also resulting in greater training and competition participation in-season. Further, greater pre-season participation may reduce the risk of injury in the ensuing in-season competition period. Similarly, players who complete less pre-season training, also complete less training and compete in fewer matches during the following season. These findings hold important ramifications for practitioners involved in the physical development and preparation of players. Particularly, there is a need to develop strategies to maximize participation in pre-season training as this may result in a greater proportion of the squad available for training and selection during the competitive phase of the season.

Conclusions

This is the first study to examine the relationship between the amount of pre-season training completed and subsequent training load and injury during the ensuing competitive season in elite Australian football players. Our findings demonstrate that players who are able to complete a greater amount of pre-season training are able to maintain higher training loads during the ensuing season, and similarly, players who complete less pre-season training also complete less training and fewer competitive matches during the in-season phase.

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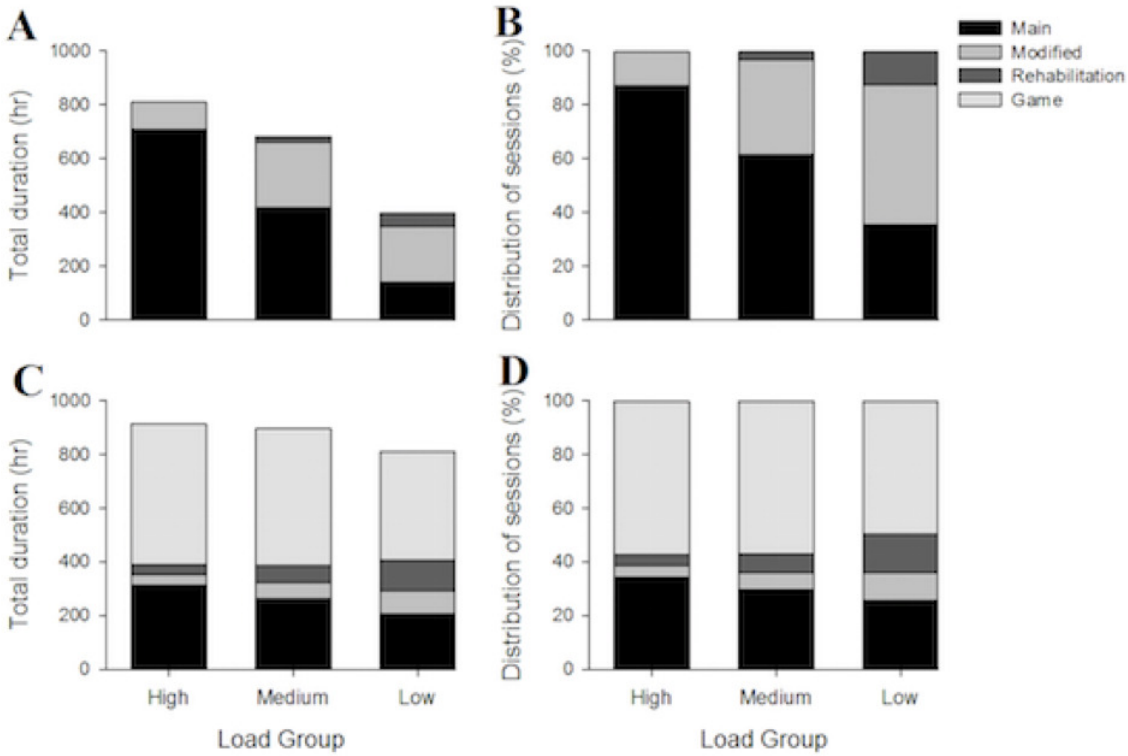
Figure Legends

Figure 1. Total duration of training hours during the pre- (A) and in-season (C) periods, with proportion of sessions completed for each load group (i.e. high, medium, and low) during the pre- (B), and in-season (D) period.

Figure 2. Quantification of weekly training and game loads (i.e. total loads) throughout the first and second half of the in-season period for each load group (i.e. high, medium, and low).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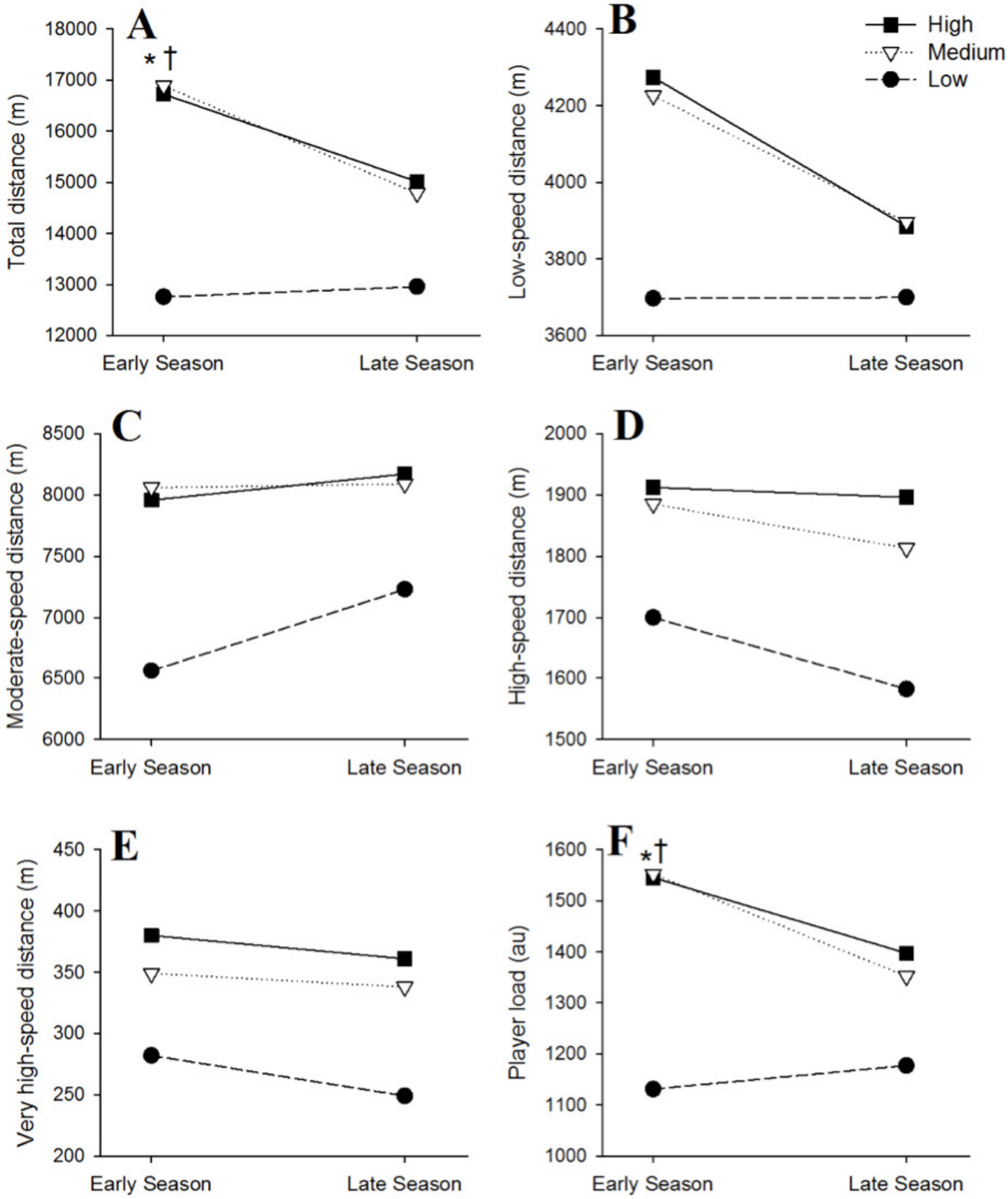
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1500
450
400
350
300
250
200
1600
1500
1400
1300
1200
1100
1000
Early Season
Late Season

Table 1. Quantification of weekly training and game loads throughout the pre- and in-season period for each load group (i.e. high, medium, and low).

Variables	Pre-Season			In-Season		
	High	Medium	Low	High	Medium	Low
Absolute						
Total distance (m)	21580 ± 7255 [*†ab]	17377 ± 7928 [†b]	12356 ± 9472	15833 ± 7898 [b]	15792 ± 7666 [b]	12758 ± 8189
Low-speed distance (m)	5931 ± 1868 [*†ab]	4976 ± 2114 [†b]	3495 ± 2590	4071 ± 2143	4054 ± 2184	3640 ± 2336
Moderate-speed distance (m)	10023 ± 3431 [*†ab]	7879 ± 3656 [†b]	5631 ± 4481	8068 ± 4538 [b]	8075 ± 4723 [b]	6850 ± 4724
High-speed distance (m)	4560 ± 2206 [*†ab]	3709 ± 2181 [†b]	2704 ± 2286	1903 ± 1052 [b]	1847 ± 1053 [b]	1666 ± 1274
Very high-speed distance (m)	1048 ± 744 [*†ab]	822 ± 648 [†b]	498 ± 532	370 ± 258 [†b]	343 ± 263 [†b]	267 ± 289
Player load (au)	1900 ± 670 [*†ab]	1538 ± 733 [†b]	1082 ± 855	1468 ± 745 [b]	1447 ± 731 [b]	1141 ± 763

All data are mean ± SD.

[*] Denotes significantly different from medium group.

[†] Denotes significantly different from low group.

[a] Denotes practically meaningful difference from medium group.

[b] Denotes practically meaningful difference from low group.

Table 2. Relationships among the percentage of pre-season completed, match availability, pre-season training load, and in-season training load.

Variables	% Pre-season completed	Pre-season TD	Pre-season HSD	Pre-season VHSD	In-season TD	In-season HSD	In-season VHSD	Match availability
% Pre-season completed	1.00	0.96 *	0.86 *	0.69 *	0.24	0.13	0.21	0.31 *
Pre-season TD	0.96 *	1.00	0.95 *	0.74 *	0.30 *	0.26	0.29	0.36 *
Pre-season HSD	0.86 *	0.95 *	1.00	0.80 *	0.30 *	0.36 *	0.34 *	0.34 *
Pre-season VHSD	0.69 *	0.74 *	0.80 *	1.00	0.30 *	0.44 *	0.53 *	0.28
In-season TD	0.24	0.30 *	0.30 *	0.30 *	1.00	0.75 *	0.60 *	0.95 *
In-season HSD	0.13	0.23	0.36 *	0.44 *	0.75 *	1.00	0.80 *	0.62 *
In-season VHSD	0.21	0.29	0.34 *	0.53 *	0.60 *	0.80 *	1.00	0.53 *
Match availability	0.31 *	0.36 *	0.34 *	0.28	0.95 *	0.62 *	0.53 *	1.00

* Denotes a significant correlation ($p < 0.05$). TD = Total distance. HSD = High-speed distance. VHSD = Very high-speed distance.