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Quantification of internal and external training load during a training camp in senior international female footballers

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ABSTRACT

Objective: This study aimed to quantify the internal and external training load profile of an international training camp and identify any differences between positional groups or starting status.

Methods: 18 players were sampled using a global positioning system (GPS) and internal training load (TL) via session rate of perceived exertion (RPE).

Results: Internal and external training load variation was present across all six individual training sessions. Results indicated match day −7 (MD-7), had significantly (P= 0.001) less training volume (3339.5 m) than all other training sessions. MD-5 and MD-2 were the most intense (387.5 and 201 m very high speed running (VHSR) and 187.5 and 49 m sprint distance (SPD) respectively in combination with large volume (5933.5 and 5151.5 m). Differences in playing position and starting status were observed in MD-2. Forwards (FW) covered significantly greater distances of VHSR (P= 0.008) and SPD (P= 0.008) in comparison to midfielders (MF) whilst starters reported significantly (P = 0.013) higher internal training loads (TL).

Conclusion: This study provides the first report on training load in elite female footballers during an international training camp including a competitive fixture highlighting the undulation of training loads across the individual training sessions, playing positions and starting status.

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KEYWORDS
Monitoring; periodisation; taper; soccer; GPS

Introduction

The use of integrated technology to quantify training loads has become common practice in elite football environments as it can provide practitioners with objective evidence to design appropriately periodised training programs (Malone et al. 2015; Akenhead and Nassis 2016). The unpredictable nature of football training and match play in conjunction with the influence of tactics and playing positions on running demands highlights the importance of monitoring training load data on an individual level (Halson 2014). Monitoring the total training loads undertaken by individual players can lead to an improved capability to identify whether positive training adaptations, fatigue, or increased susceptibility to injury have occurred in response to the training programme (Halson 2014). Training load can be categorised as internal or external, with the monitoring of both deemed to be best practice as the objective external load can contextualise an individual's subjective internal load (Halson 2014). Internal training load refers to the level of physiological stress undergone by the athlete during training or competition whilst external load has been defined as the total work done by the athlete during training or competition (Impellizzeri et al. 2005). Through the periodisation of training volume and intensity practitioners can ensure players are optimally prepared to perform (Impellizzeri et al. 2005; Malone et al. 2015).

Due to the time constraints imposed by increased training, travel and competition schedules in female international football, full recovery post-match play may not always be possible (Datson et al. 2014). Consequently, implementing adequate recovery from the training load sustained at club level whilst also ensuring sufficient training load exposures to ensure international competition readiness can present a complex scenario (Buchheit and Dupont 2018). In addition, due to club and international team commitments international level players frequently take part in periods of congested fixtures exposing them to a heightened risk of acute and overuse injury (Carling et al. 2016).

The physical demands of international football significantly differ from that of club level with increased levels of high-speed running, sprinting (Mohr et al. 2008; Andersson et al. 2010) and repeated sprint ability observed at international level (Gabbett 2010). Such actions are heavily influenced by a player's acceleration and deceleration capabilities. Higher level athletes have been shown to possess the capacity to maintain a greater frequency and magnitude of both (Harper et al. 2019). When executed over a prolonged period of time (e.g., during match play), accelerations and decelerations in particular provoke muscle damage (Harper et al. 2019), inhibiting neuromuscular function and resulting in neuromuscular fatigue (Nédélec et al. 2012; Balloch 2018). The manifestation of neuromuscular fatigue has been demonstrated in elite female footballers up to 72 hours post-match play (Andersson et al. 2008). Consequently, in a national team setting, players may present with symptoms of acute or residual fatigue during preparation for competitive match play (Nédélec et al.

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2012). Furthermore, in a national team setting effective management of fatigue is crucial, as decisions on player readiness and neuromuscular fatigue are frequently required (Pyne and Martin 2011; Thorpe et al. 2017). As club-level games can occur 48 to 72 hours prior to international camps, training loads may have to be adapted in the initial stages of the camp to negate the effects of fatigue from club performances and ensure players are optimally prepared for international competition (Pyne and Martin 2011).

Hägglund et al. (2013) highlighted high player availability and a low injury burden rate in elite male football to be a main contributor to team success. Developing a greater understanding of the training load sustained by players transitioning from international to club teams may assist in training prescription decision making and reduce the risk of injury (McCall et al., 2015). At present information on the total training loads experienced by international football players is scarce (Noor et al. 2019). International training camps or competitions can prove to be a difficult period for national team or club practitioners in terms of consistently monitoring the total training load of players due to logistical and data sharing challenges as well as access to resources and player adherence (McCall et al. 2015; Buchheit and Dupont 2018). However, practitioners within an international environment have advocated the use of training load monitoring in order to assist in injury risk reduction strategies (McCall et al. 2015)

Limited research exists on total training loads withstood by elite male international footballers (McCall et al., 2014; Noor et al. 2019). Although various aspects of GPS-based external training load metrics have been analysed during international competition in female international footballers (Hewitt et al. 2014; Trewin et al., 2018; Datson et al., 2017; Ramos et al., 2017; Ramos et al. 2019), no study has quantified the internal and external training load of female international footballers over the course of a training camp or by position. Therefore, the purpose of the study was to quantify the internal and external training load profile of an international training camp and identify any differences between positional lines or starting status.

Materials and methods

Experimental overview

Eighteen football players with (age = 24.2 ± 4.4 years; height = 171.7 ± 5.3 cm; and weight = 64.1 ± 5.8 kg), from a senior female international team placed 33rd in the FIFA rankings participated in this study. Participants were categorised according to playing position as defenders (n = 7), midfielders (n = 6) and forwards (n = 4). Players were classified by their positional line as defender (DF), midfielder (MF) and forward (FW) as well as by starting status (starter and non-starter). The study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained by the College Research Ethics Committee. The participants were informed of the risks of the study in person and writing and signed an informed consent document before the beginning of data collection and were free to withdraw from the study at any time.

Data was collected over a one-week period during an international training camp prior to a tournament qualifying group fixture versus a team ranked 98th in the FIFA rankings. The days of training were classified as match day minus −7 (MD-7), −6 (MD-6), −5(MD-5), −3 (MD-3), −2 (MD-2), −1 (MD-1) and match day (MD). No training took place on (MD-4) as it was a scheduled rest day. In total 108 individual training observations were collected during this period. Players who did not take full participation in pitch sessions in conjunction with items outside the researchers control, i.e. (equipment technical issues) lead to a further seven individual training observations being excluded, leaving 101 individual training observations available for analysis. Participants were fitted with a GNSS Apex (STATSports, Northern Ireland) GPS unit before each session. Researchers attended all sessions in an observational capacity and in no way influenced training content. Data collection was carried out at training camp and match day venues.

External training load

The players' physical activity during each training session was measured using portable GPS technology (Apex, STATSports, Newry). This method of measurement has been shown to be reliable and valid (Beato et al. 2018). The device provides position, velocity and distance data at frequency of 10 Hz. Each player wore a GPS device between the left and right scapula in a custom-made vest supplied by the manufacturer. This position has been shown to be reliable and valid in the measurement of the physical activity associated with team sports (Coutts and Duffield 2010). All devices were activated 30-minutes before data collection to allow acquisition of satellite signals and synchronise the GPS clock with the satellites atomic clock (Maddison and Mhurchu 2009). To eliminate inter-unit variability, each individual player was assigned the same GPS device for each training session (Buchheit et al. 2014). Variables that were selected for analysis, total distance (TD), very high speed running (VHSR), accelerations > 3 $m.s^{-2}$, decelerations > 3 $m.s^{-2}$, number of sprints (SP), sprint distance (SPD). The speed zones of very high-speed running and sprinting were broken down into the following thresholds: (5.28–6.25 $m. s^{-1}$), and (>6.25 $m. s^{-1}$) specifically recommended by Park et al. (2019) for external load assessment in elite female footballers.

Internal training load

Internal training load was calculated for each individual player post-training session using a rating of perceived exertion (SRPE) based on Fosters modified version of the rate of perceived exertion scale developed by Borg (Borg 1970; Foster et al. 2001). Each participant rated the training session or match on a scale of 0–10 with 0 = rest and 10 = maximum effort. The (RPE) figure selected by the participant was then multiplied by the duration of the session e.g. (RPE of 8 × 50 minutes training session) = training load of 400 arbitrary units (TL). Participants individually provided their (RPE) rating to researchers within 30 minutes of the session. Following each training session or match play the internal training load data were calculated whilst the GPS data were downloaded using the (Apex 10 Hz version 2.0.2.4) software. Both data sets were then collated and securely stored in a purpose-built database for analysis.

Statistics

Shapiro Wilks and Kolmogorov-Smirnov tests rejected data normality. As a result, non-parametric repeated measures ANOVA (Friedman test; $P \leq 0.05$) with Wilcoxon signed rank test using Bonferroni adjustments for post-hoc analysis of all training days. Variation in positional lines (DF, MF, FW) were analysed using the Kruskal-Wallis test, followed by the Mann-Whitney U test with Bonferroni correction for all pairwise comparisons. Statistical analyses of differences in starting status were conducted using the Mann – Whitney U test. To determine the magnitude of difference between testing sessions effect size (r) was calculated by Z (standardised test statistic) divided by the square root of N (i.e., number of cases) and values of 0.2,0.5, and 0.8 were interpreted as a small, medium and large respectively (Cohen 1988). All statistical analyses were conducted using the statistical package for the social sciences (SPSS, version 25.0, SPSS Inc., Chicago, IL, USA).

Results

The results of the Friedman and Wilcoxon signed rank test indicated significant changes in internal and external training load variables across all training sessions. Statistically significant linear progressions in training volume and intensity were observed from MD-7 peaking on MD-5. Total training load underwent statistically significant reductions in both MD-3 and MD-1 whilst MD-7 represents the lowest total training load of all training session. Refer to Table 2 for a comparison of each individual training session internal and external training load.

Kruskal-Wallis test revealed a statistically significant difference in VHSR, SPD and SP between positions (DF, n = 7: MF, n = 7: FW, n = 4) on MD-2. FW completed significantly greater distances of VHSR (P = 0.008, r = 3.03), SPD (P = 0.008, r = 3.04) and SP (P = 0.02, r = 2.68) than MF. No significant differences were established between external and internal training load variables in all other training sessions due to playing position. Mann Whitney U test revealed a significant difference in the training load (TL) reported on MD-2 between starters (Δ = 558, *n*= 10) and non-starters (Δ = 418, *n*= 8), *U* = 13, z = – 2.47, P = .013, r = .58. No significant differences were established in external and internal training load variables in all other training sessions due to starting status.

Discussion

The purpose of this study was to quantify the internal and external training load undergone by players during an international training camp. This study revealed that the total training load (internal & external training load) throughout the training camp was prescribed in an undulating non-linear method with a degree of variation (Figure 1). This is a method which has been advocated for in the periodisation practices designed for team sports (Gamble et al. 2006). Due to the paucity of evidence on total training loads endured by female international footballers the comparisons made in this study are against male youth and first teams (Clemente et al. 2019; Stevens et al. 2017; Anderson et al. 2016a; Coutinho et al. 2015). The research conducted on training loads in football predominately emanates from elite male professional clubs (Noor et al. 2019).

Training peaked on MD-5 as all examined training load variables significantly increased in comparison to MD-6 and MD-7 indicating a progressive increase in training volume and intensity (Table 2). A significant decrease in volume and intensity was evident on MD-3 due to reductions TL (P = 0.001, r = .60), TD (P = 0.001, r = .60), VHSR (>5.28 $m.s^{-1}$) (P = 0.001, r = .61) and SPD (>6.25 $m.s^{-1}$) (P = 0.00, r = .62). Previous research trends within the literature demonstrate a progressive reduction in total training load from a mid-week peak to MD-1 (Coutinho et al. 2015; Anderson et al. 2016aa; Stevens et al. 2017; Clemente et al. 2019) with significant reductions in volume and intensity in the final 48 hours prior to match-play to facilitate a taper, promote recovery and ensure competition readiness (Anderson et al. 2016b).

However, this study refutes some of the previously reported findings within the literature. Similar to Clemente et al. (2019), Stevens et al. (2017) and Coutinho et al. (2015) a peak in training volume and intensity is visible mid – week. Unlike the aforementioned research a progressive decline in TD, VHSR, accelerations and decelerations was not apparent across the later part of week. MD-2 illustrates a rise in volume and intensity identified by statistically significant increases in TL (P = 0.03, r = .37), TD (P = 0.002, r = .54), VHSR (P = 0.002, r = 5.2), SP (P = 0.002, r = .53) and SPD (P = 0.002, r = .52) in comparison to MD-3 values (Table 2). As a result, the taper period to dissipate fatigue, promote recovery and ensure competition readiness prior to competitive match-play is conducted over a 29-hour period as opposed to the 48-hour period previously cited within the literature (Clemente et al. 2019; Stevens et al. 2017; Anderson et al. 2016a; Coutinho et al. 2015).

The levels of accelerations sustained on MD-2 were statistically significantly different from MD-5 (P = 0.02, r = .08) though the magnitude of the difference was trivial. There was no difference in the levels of decelerations (P = .962, r = .01) performed between MD-2 and MD-5. However, the volume of VHSR and SPD sustained on MD-2 were reduced by 48% and 73% respectively, potentially demonstrating how training session content was altered to optimise player readiness for competition on MD (see Table 1). The optimum taper period for female international match play has yet to be clarified within the literature so future studies should investigate the most effective periodisation strategies in order to achieve optimal readiness for match day performance.

A winning performance was produced and players that completed the whole game covered similar mean TD (9389 ± 368 m) as other female international cohorts during

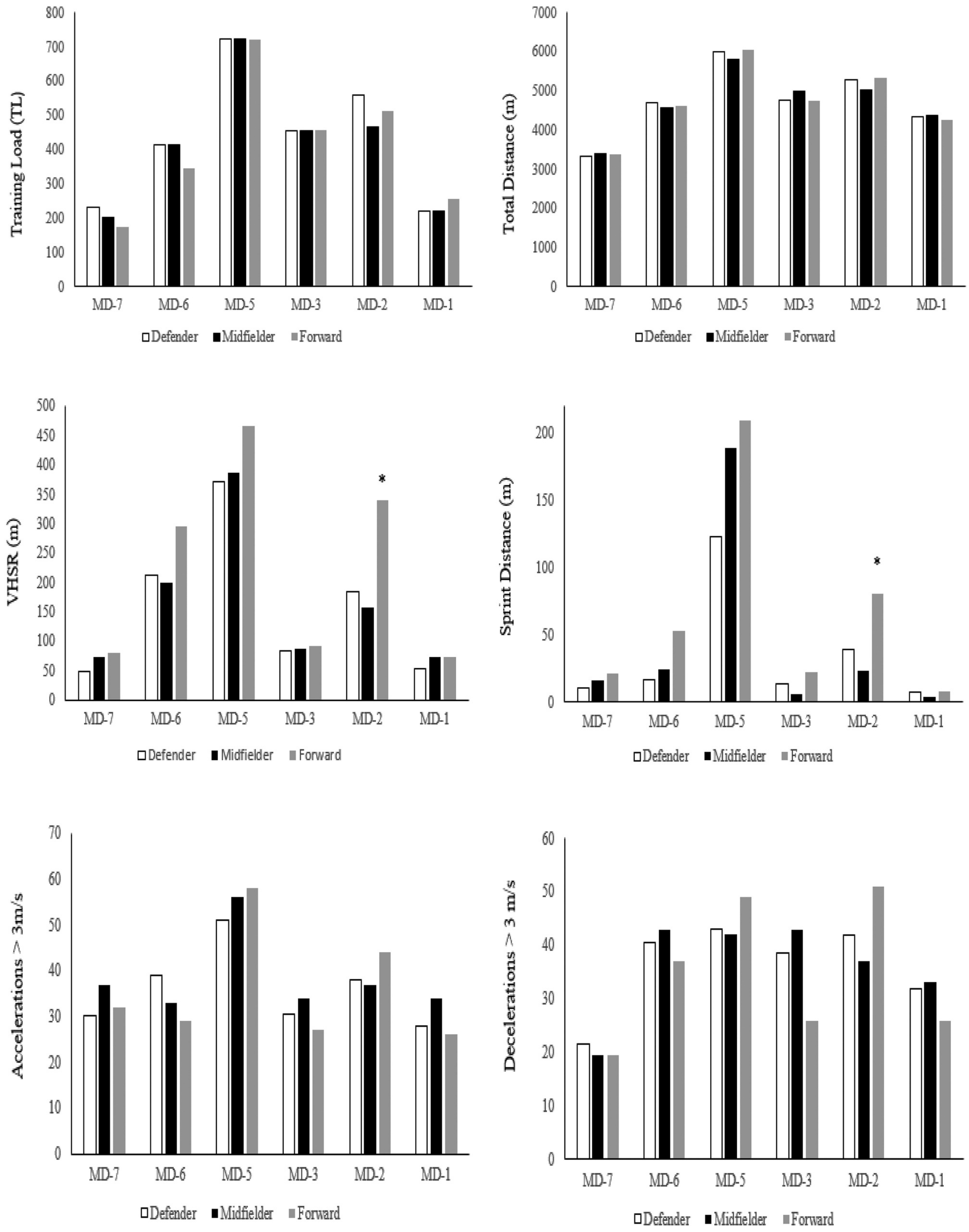

Figure 1. Descriptive statistics (median) of playing positions internal training load, total distance, very high speed running, sprint distance, accelerations and decelerations > 3 m. s and internal training load on all training sessions. * denotes significantly different to midfielder, P ≥ 0.05.

match play (Hewitt et al. 2014; Ramos et al. 2019). The combination of contextual factors of match-play (i.e., tactics, formation and level of opponent) as well as differences in the technology and velocity thresholds utilised inhibit direct comparisons between studies of external load variables such as VHSR and SPD (Ramos et al. 2019; Trewin

Table 1. Camp training sessions schedule, pitch sizes and duration.

Training Session	MD-7	MD-6	MD-5	MD-4	MD-3	MD-2	MD-1	MD
Start Time	15:30	11:00	11:00		11:00	11:00	14:30	19:30
	Warm up Passing (40 x 30 m) 5 x 5 + 6 (35 x 35 m) 11 vs 11 (100 x 69 m)	Warm up Passing (25 x 20 m) Possession (35 x 35 m) 9 vs 9 (75 x 69 m)	Warm up 4 v 2 (5 x 5 m) Defending Possession (15 x 20 m) 1 vs 1 Sprints (3 x 7 × 15 m) 9 vs 9 (75 x 69 m)	Rest Day	Warm up 2 vs 2 (12 x 12 m) 5 vs 5 + 1 (35 x35) 3 vs 2/2 vs 1 (35 x 20 m) 9 vs 9 (100 x 69 m)	Warm up 1 vs 1 Defending (10 x 15 m) Possession (20 x 15 m) 11 vs 11 (100 x 69 m)	Warm up 4 vs 2 (11 x 11 m) 5 vs 5 + 3 (30 x 30 m) Shooting (40 x 20 m) 4 vs 4 + 2 (20 x 30 m) 11 vs 11 Set pieces (100 x 69 m)	Match (100 x 69 m)
Duration (mins)	58	69	103	0	91	93	73	95

Table 2. Descriptive statistics median (Md) & range external and internal training load and post-hoc analysis.

Variable	MD-7	MD-6	MD-5	MD-3	MD-2	MD-1
Session RPE (Srpe)	3.5 (1–4)	6 (3–6) a	7 (4–7) a, b	5 (3–7) a, c	5.5 (3–7) a, c	3 (2–5) b, c, d, e
Training Load (TL)	203 (58–232)	414 (207–414) a	721 (412–721) ab	455 (273–637) a, b, c	511.5 (279–651) a, b, c, d	219 (146–365) a, b, c, d, e
Total Distance (m)	3339.5 (2916–3714)	4604.5 (4175–4964) a	5933.5 (5416–6387) a, b	4821.5 (4195–5089) a, b, c	5151.5 (4505–5474) a, b, c, d	4330 (3653–4708) a, b, c, d, e
VHSR (m) (> 5.28 m.s^{-1})	57.5 (9–217)	188.5 (142–356) a	387.5 (279–543) a, b	96 (9–196) a, b, c	201 (98–367) a, c	59 (21–98) b, c, e
Sprint Distance (m) (> 6.25 m.s^{-1})	12 (0–64)	22.5 (5–78) a	187.5 (95–321) a, b	12.5 (0–61) a, b, c	49 (6–82) c, d	6 (0–23) b, c, e
No. Sprints	0 (0–64)	2 (2–5) a	12.5 (5–18) a, b	1 (0–3) c	2.5 (0–7) a, c, d	0 (0–2) b, c, e
Accelerations (> 3 m.s^{-2})	34 (17–61)	32 (21–48)	56 (31–72) a, b	31.5 (22–53) c	40.5 (24–61) b, c	28 (18–52) a, c, e
Decelerations (> 3 m.s^{-2})	21 (14–32)	41 (24–53) a	45.5 (24–64) a,b	41 (18–56) a	44.5 (33–63) a	32.5 (22–39) a, b, c, d, e

(statistically significantly different from MD-7, a; MD-6, b; MD-5, c; MD-3, d; MD-2, e; MD-1, f)

et al.,2018; Datson et al., 2016; Hewitt et al. 2014; Andersson et al. 2010). Considering the scarcity of published data on the internal and external training loads sustained by senior female footballers at club and international level and inconsistencies in study protocols further investigation on the topic is warranted.

In terms of playing position, differences in external load metrics such as TD, VHSR, SPD, accelerations and decelerations during match play (Hewitt et al. 2014; Datson et al. 2017; Ramos et al. 2019) as well as differences in internal training load reported during various sized small sided games have been documented within the literature (Owen et al. 2016). In contrast the positional analysis in this study confirmed no significant difference in the TL, TD, VHSR, SPD, accelerations, decelerations, experienced between the three positional groups except on MD-2 were FW completed more VHSR (340 m) SPD (80.5 m) in comparison to MF, VHSR (156 m) SPD (23 m) (see Figure 1). Positional variations in running demands are well established with regards to match play (Datson et al. 2017) and have been consistently replicated in elite female international footballers across numerous age grades (Ramos et al. 2019). In terms of training, playing position has been shown to influence sprint distance covered ($P = 0.009$) in small sided games and tactical and technical drills but not very high speed running ($P = 0.131$) (Ramos et al. 2019). The observed differences between FW and MF on MD-2 are probably related to the 1 vs 1 and 11 vs 11 training drills (*see* Table 1) combined with the influence of playing style and tactics to be employed on match day.

Analysis of starting status identified only one significant difference as starters reported higher levels of TL on MD-2 ($P = 0.013$, $r = .58$) in comparison with non-starters (see Figure 2). On MD-2 starters performed 22% more accelerations and 24% more decelerations than non-starters which represented a small (ES = .22) difference for both. Taking in to account non-starters covered marginally more TD, VHSR and SPD on MD-2 and considering accelerations and decelerations have been shown to contribute to neuromuscular fatigue this may explain why starters reported greater levels of internal training load on MD-2 (Harper and Kiely 2018; Harper et al. 2019). Previous research by Anderson et al.

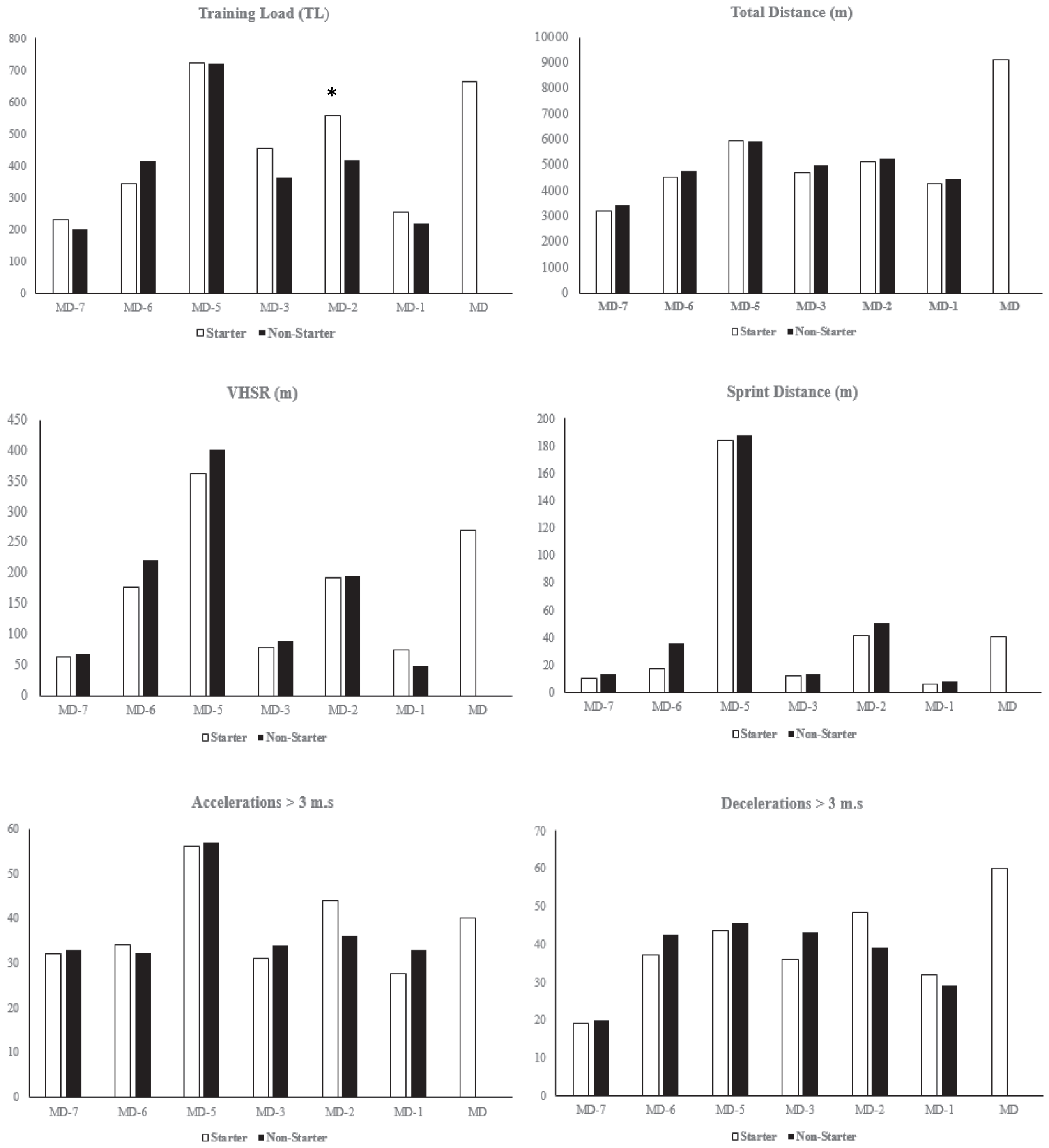

Figure 2. Descriptive statistics (median) of starters and non -starters internal training load, total distance, very high speed running, sprint distance, accelerations and decelerations > 3 m. s^{-2} and internal training load on all training sessions. * denotes significantly different to non-starters, $P \geq 0.05$.

(2016a) showed an absence of significant differences in TD, VHSR and SPD covered between starters and non-starters during training. Furthermore, when quantifying high-intensity external training load variables such as high-speed running and sprinting throughout a season Anderson et al. (2016a) demonstrated the differences between starters, and non-starters were primarily attributable to match play. The results of this study concur with the conclusion of Anderson et al. (2016a) as no differences in VHSR and SPD between starters and non-starters were evident during training, whilst starters depending on playing position covered a range of VHSR (77–442 m) and SPD (0–88 m) on MD.

Limitations

This study is reflective of a specific cohort of senior female international footballers and the total training load sustained during a training camp prior to a competitive fixture and may not be representative of the internal and external training load undertaken by other international teams. Furthermore, formation and tactics have all been shown to have an influence on the running demands of match play. Thus, it must be acknowledged that the structure of training and the total training load sustained by players may potentially vary from training camp to training camp (Noor et al. 2019). One potential explanation for the lack of significant variation in internal and external training load reported between the positional lines within the present study may be due to grouping the positional lines DF, MF, and FW. This meant that defenders with different tactical roles (e.g., centre-backs and full-backs) were grouped together. It is possible that differences in internal and external training loads between different defensive, midfield and attacking positions were present. Therefore, the possibility to underestimate or overestimate an individual player's total training load may be present as the influence of the teams playing style and tactics is potentially negated (Rampinini et al. 2007).

Additionally, arbitrary GPS thresholds for VHSR, SPD, acceleration and deceleration were applied to monitor the external training load running performances in this current study. By implementing arbitrary GPS thresholds, a player's VHSR and SPD can potentially be under or overestimated depending on their individual physical attributes (Abbott et al. 2018a). As a result, the generalisations of the result of this study must be approached with caution. Future investigations should assess individually set GPS thresholds based on each individual player's physical capacity. This approach might highlight each individual player's relative intensity of external training load sustained and may afford coaches the opportunity to make more informed decisions regards individualised training load prescription (Halson 2014; Abbott et al. 2018a, 2018b).

Conclusion

In summary, this study systemically quantified the internal and external training load experienced by female senior international footballers across a training camp in preparation for a competitive fixture. The data from the study revealed internal and external training load variation between the individual training sessions whilst positional and starting status training load differences were only confirmed on (MD-2) of the camp. Future studies should investigate whether this method of training load prescription and periodisation effectively limits fatigue and optimises player readiness for match day performance. Such investigations would have to take factors such as playing style, tactics and opposition level into account to provide a more accurate understanding of the optimal training load required for an international training camp prior to a competitive fixture.

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Disclosure statement

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