External and internal loads during the competitive season in professional female soccer players according to their playing position: differences between training and competition

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Abstract

The aim of this study was to compare external (EL) and internal loads (IL) during training sessions compared to official matches in elite female soccer players according to their playing position.

Training and match data were obtained during the 2017/18 season from eighteen players (age: 26.5±5.7 years; height: 164.4±5.3 cm; body mass: 58.56±5.58 kg) from a first Division Spanish team. The EL (total distance covered; high speed running distance; number of accelerations and decelerations) was assessed with a global positioning system (GPS) and triaxial accelerometer. The IL was assessed with ratings of perceived exertion (RPE; and session-RPE).

The EL and the IL from official matches were higher compared to training sessions ($p<0.05$; effect size [ES]: 0.6-5.4). In official matches, the EL was greater in Attackers (AT) and Central Midfielders (CM) versus Central Backs ($p<0.05$; ES: 0.21-1.74). During training sessions, the EL was similar between playing positions ($p>0.05$; ES: 0.03-0.87). The EL and the IL are greater in official matches compared to training sessions, with greater match-related EL in AT and CM players. Current results may help practitioners to better understand and modulate training session's loads according to their playing position, potentially contributing to their performance readiness and injury risk reduction.

Keywords: sports; sports medicine; human physical conditioning; soccer; female; women.

Introduction

Information regarding the external (EL) and internal loads (IL) from official matches and training sessions may provide practitioners working in elite soccer the necessary information to plan suitably challenging training sessions that ultimately improve performance (Bartlett et al., 2017) and decrease injury risk (Colby et al., 2014; Hulin et al., 2016). Whilst, EL refers to the external work completed by the player (e.g. distance cover), IL refers to the internal response imposed from training (e.g. heart rate or RPE) and is therefore widely accepted as a method to monitor and optimize training prescription (Impellizzeri et al. 2004). Moreover, such information may help into the optimization of both pre- and post-match training sessions adjusting the optimal load to avoid fatigue status in the matches. ~~This information is particularly relevant in female soccer, rapidly gaining in popularity around the world.~~ However, whilst some studies have described and compared the EL and IL from official matches and training sessions in elite male soccer players (Anderson et al., 2016; Malone et al., 2015; Stevens et al., 2017), the same does not hold true for elite female soccer players. Although tempting, findings from male soccer players should not be simply translate to female players due to several potential differences between such groups, including physiological characteristic, physical fitness, training background and playing style. Moreover, it is unknown whether the higher rate of injuries in women's soccer (Crossley et al. 2020) is related to discrepancy in match loads and training load prescription/periodization. Therefore, a better understanding regarding how the EL and IL of elite female soccer players during training sessions align with those from official matches deserve further research attention.

Although the behaviour of the EL in elite female soccer players during training sessions and official matches had not been compared, some studies have described the EL and its relevance to elite female soccer (Datson et al., 2017; Krustrup et al., 2005; Mohr et al., 2008; Ramos et al., 2019; Vescovi & Favero, 2014). In competition, elite female soccer players cover a total distance of 9-11 km, of which 590-840 m is at high intensity (15.6-20 $km \cdot h^{-1}$) and 198-379 m is covered during sprinting ($\geq$20 $km \cdot h^{-1}$). Datson et al. (2016) reported that 24% of total distance covered (2,520 m) in elite female soccer during domestic-level matches was in the high-speed zone (>14.4 $km \cdot h^{-1}$) (Datson et al., 2017). High-speed zone running is crucial as it directly impacts on match performance and goal scoring opportunities (Faude et al., 2012). Ramos et al. (2017) also described the accelerations ($\geq$ $1 m \cdot s^{-2}$) and decelerations ($\leq$ $-1 m \cdot s^{-2}$) for elite female players in international competition reaching up to 217.6±22.4 accelerations and 176.1±29.6 decelerations per match. The EL, however, may change according to factors such as the position of the player in the field (Akenhead et al., 2016; Datson et al., 2014; Ramos et al., 2019; Vescovi & Favero, 2014)

Besides the relevance of EL in elite female soccer players during official matches, IL (usually assessed as players' ratings of perceived exertion [RPE]), also is a key aspect to consider to know the individual responses to similar EL. The EL are linked to physiological and biomechanical demands (Vanrenterghem et al., 2017). Ultimately, understanding the interplay between EL and IL is vital to the monitoring of fitness and fatigue, and subsequent planning of training and recovery. However, despite a growing body of scientific literature on IL during training sessions and official matches in male soccer players (Jaspers et al., 2017; Los Arcos et al., 2017; Lu et al., 2017), studies in elite female soccer players are lacking. Accordingly, due to the lack of information, it is not unconceivable that typical training sessions are not being optimally programmed for playing positions in terms of preparing for and recovering from match-play. Moreover, potential discrepancy between match and training load, or playing position may contribute to the higher injury rates in female soccer (Crossley et al. 2020).

Therefore, there is a lack of studies in elite female soccer players regarding comparison of the EL and the IL during training sessions versus official matches, and a lack of studies analyzing such potential differences according to player's position on the field. Accordingly, due to the lack of information, it is not unconceivable that typical training sessions are not being optimally programmed for playing positions in terms of preparing for and recovering from match-play. Moreover, potential discrepancies between match and training load, or playing position may contribute to the higher injury rates in female soccer (Crossley et al. 2020). Therefore, the aim of this study was to compare the EL and the IL during training sessions compared to official matches in elite female soccer players according to their playing position. Based on relevant studies carried out in elite male players (Malone et al., 2015; Stevens et al., 2017), we hypothesized that EL and IL during training sessions will be greater compared to official matches in elite female soccer players, although modulated by the position of the player in the field (Akenhead et al., 2016).

Methods

Subjects

Eighteen elite female soccer players with a mean (± standard deviation [SD]) age, height and body mass of 26.5±5.7 years, 164.4±5.3 cm, and 58.56±5.58 kg, respectively, with 1-14 years of 1st National Division level experience, participated in this study. Players were analysed according to their match position: central backs (CB: n=3; GPS files=113), wide backs (WB; n=3; GPS files=89), central midfielders (CM: n=6; GPS files=135), wide midfielders (WM: n=4; GPS files=67) and attackers (AT: n=2; GPS files=49). The team competed in Liga Iberdrola (1st Spanish Division) in the 2017/2018 season. The weekly schedule consisted of one match on Sunday, two rest days (Tuesday and Saturday), and a team training session on each of the remaining days. Data arose from the daily player monitoring over the course of the season. All players were notified of the aim of the study and procedures in accordance with the Declaration of Helsinki. The study was approved by the ethical committee of the ***blank for review purposes*** University.

Design

Over a five-month period during the in-season competitive period, 452 observations were undertaken, 358 of training sessions and 94 of official matches. Only data derived from starting players that completed ≥85% of match duration, and participated in all training sessions the following week were included. Due to these considerations, 20-60 observations per player were obtained, including training and official matches. Based on previous recommendations, training load data were analysed with respect to the number of days before or after a match day (MD) (Akenhead et al., 2016). The weekly analysis consisted of: i) MD on Sunday; ii) MD+1 on Monday (recovery session); iii) off-day on Tuesday; iv) MD-4 on Wednesday (conditioning and tactical session, integrated in small and medium sided games), v) MD-3 on Thursday (conditioning and tactical session, integrated in medium and large sided games), vi) MD-2 on Friday (skills and strategy exercises; taper day), vii) off-day on Saturday. For training sessions players were monitored for the entire session (including on-pitch warm-up), for matches they were monitored from the start of the match until the final whistle, and the warm-up was not included. Gym sessions and compensatory sessions that non-starting players performed the day after the match were not included in this study.

Procedures

The EL was measured using a GPS device (SPI Pro X, GPSports Systems, Australia) worn in a harness between the scapulae. The device comprises a 5 Hz GPS microcontroller and a proprietary interpolation algorithm that outputs positional data at 15 Hz. The device also incorporates a 100 Hz triaxial accelerometer. The reliability and validity of the GPS system have been previously reported (CV: 0.3-2.9%) (Scott et al., 2016). Data from each GPS unit were downloaded and analysed using a commercially available software (v.R1.215.3, Team AMS, GPSports System, Australia).

In accordance with the load-adaptation framework presented previously (Vanrenterghem et al., 2017), we selected the following markers of *physiological* EL: i) total distance (TD) in absolute (m) and relative values ($m \cdot min^{-1}$), ii) high speed running distance (HSRD; i.e., >15 $km \cdot h^{-1}$) in absolute (m) and relative values ($m \cdot min^{-1}$). As markers of *biomechanical* EL we selected i) number of accelerations <1 $m \cdot s^{-2}$ (AC1) and >1 $m \cdot s^{-2}$ (AC2), ii) number of decelerations >1 $m \cdot s^{-2}$ (DC1) and <1 $m \cdot s^{-2}$ (DC2), iii) body load (arbitrary units [AU]). As previously indicated (Gomez-Piriz et al., 2011), the acceleration and deceleration variables were calculated from the second derivative of the GPS position data, whilst the body load variable is a cumulative measure of changes in accelerations measured with the accelerometer. The aforementioned outcomes were represented as a percentage of the total match/training duration. The mean value of each training session was expressed in absolute values and relative to the mean EL registered during official matches: (mean training-session EL ÷ mean match EL) × 100.

For the IL, as previously suggested (Impellizzeri et al., 2004), the marker was RPE and session-RPE (sRPE). In accordance with the procedures suggested by Foster et al. (Foster et al., 2001), the 10-point Borg scale was used to obtain each player RPE 15-30 minutes post-session (training or match) (Foster et al., 2001). The sRPE was determined by multiplying RPE by the duration of training sessions or matches (minutes). All players were familiarized with RPE-scales during pre-season.

Statistical analysis

Data were analysed using factorial linear mixed modelling using the software Statistical Package for Social Sciences (SPSS, version 22, Inc., Chicago, IL, USA). Linear mixed modelling can be applied to repeated measures data from unbalanced designs, which was the case in our study since players differed in terms of the number of repeated training sessions and matches they participated in. In this study, training days (MD+1, MD-4, MD-3, MD-2) and player position (CB, WB, CM, WM, AT) were treated as categorical fixed effects. Bonferroni tests were used post hoc to assess where differences occurred, with Cohen's *d* tests used to calculate effect sizes, classified as trivial (<0.2), small (>0.2–0.6), moderate (>0.6–1.2), large (>1.2– 2.0), very large (>2.0–4.0) and extremely large (>4) (Batterham & Hopkins, 2006). Data are presented as mean ± SD, or as a percentage of match duration. The significance level was set at $p < 0.05$.

Results

Table 1 displays the mean ± standard deviation for weekly EL and IL during training sessions and matches. The duration of training sessions was on average 51.6±20.4, 82.4±11.4, 78.0±16.5 and 69.8± 18.2 min for MD+1, MD-4, MD-3 and MD-2, respectively.

Comparison between match day and training sessions load

Greater relative distance covered was observed on official matches compared to training days (large - extremely large differences; Figure 1A).The players covered greater relative total distances on MD (95.19±9.21 $m \cdot min^{-1}$) compared to weekly training sessions ($p<0.01$; *ES* across training sessions = 2.04 to 5.09) (Table 1). Similarly, the players covered greater relative

HSRD on MD (12.13±2.40 $m \cdot min^{-1}$) compared to training sessions (from 2.54±2.82 up to 6.56±2.87 $m \cdot min^{-1}$; $p<0.01$; *ES* across training sessions = 2.00 to 8.20).

*****Figure 1*****
*****Table 1*****

Moreover, a greater number of accelerations and decelerations were noted during MD compared to training sessions (Figure 1B).

On MD a greater number of total accelerations (255±50) were observed compared to training sessions ($p<0.01$; *ES* = 2.4 to 5.5; Figure 1B; Table 1). During the training sessions, the number of accelerations ranged only from 34.65±33.36% up to 73.9±51.9% when expressed as a percentage of the total number of accelerations on MD. Similarly, during the training sessions, the number of decelerations ranged only from 21.2±22.3% up to 49.8±23.3% when expressed as a percentage of the total number of accelerations on MD (78±16; $p<0.01$; *ES* = 1.8 to 5.1; Table 1). Moreover, a greater body load was observed during MD (170.19±49.01 AU) compared to training sessions (between 53.79±51.78 up to 90.26±52.82 AU; $p<0.01$; *ES* across training sessions = 0.78 to 5.40).

The RPE was greater during MD (8.43±0.76) compared to training sessions (between 3.12±1.09 and 6.22±1.02; $p<0.01$; *ES* across training sessions = 2.00 to 7.86; Figure 1C). Similarly, the player's sRPE was greater during MD (792±103.1 AU) compared to training sessions (between 166.9±133.5 and 578.8±139.1 AU; $p<0.01$; *ES* across training sessions = 1.51 to 7.20; Figure 1D).

Comparison between playing positions

As indicated in Figure 1A, on MD, the CB achieved the lowest values of relative total distance covered at running speeds <15 $km \cdot h^{-1}$ compared to all other field positions ($p<0.05$), except WM. Similarly, as indicated in Figure 1C, on MD, the CB showed the lowest values of RPE compared to CM and AT ($p<0.05$). Moreover, as depicted in Figure 1D, on MD, the CB and WM showed the lowest values of sRPE compared to AT ($p<0.01$). Comparisons between playing positions during training sessions revealed no significant differences.

Discussion

The aim of this study was to compare the EL and the IL during training sessions compared to official matches in elite female soccer players according to their playing position. The EL and IL were greater during official matches compared to training sessions. Particularly, the training sessions closer to MD (MD+1 and MD-2) showed lower loads, while the training sessions in the middle of the week (MD-4 and MD-3) showed higher loads. Furthermore, while significant differences in EL and IL between playing positions were observed on MD, no significant differences between playing positions were observed within training sessions. These findings indicate that practitioners should account for playing position when designing/prescribing weekly training loads, such as designing training drills that allow AT to cover long distances at high speeds, whilst training drills for CM should involve a higher frequency of accelerations and decelerations.

The average total distances covered during the conditioning and tactical training sessions of the week (MD-4, 4831±860 m; MD-3, 4975±1318 m) were in agreement with those previously observed among female soccer players (~4950-5400 m) during a preparation camp for international tournaments, involving a block of 7-10 days of duration with 5-7 training sessions (Trewin 2017). Regarding the average total distances covered during MD-2, female players covered 3024±1220 m. The lower values observed in comparison to MD-4 and MD-3 may be explained by the nature of the MD-2 training drills, involving skills and strategy exercises, also used to taper training load before MD. Such results are in agreement with the values observed in the aforementioned study (Trewin 2017), were female players applied a taper load before a match, achieving lower values of average total distances covered (~3900-4900 m) compared to other training days. Taper strategies are common in different sport disciplines, and seems a key strategy among professional female soccer players aimed at optimize adaptations and performance before a match. For example, concerning total distances covered, greater values for the aforementioned outcomes were noted during MD-4 and MD-3 compared to MD-2. It was however beyond the scope of this manuscript to provide a full description of the observed tapering strategy on HSRD, accelerations, decelerations, body load and sRPE, let alone to make any claims concerning their potential link with performance or injury incidence (Impellizzeri et al., 2020).

In this study, the weekly microcycle had a pyramid shape, in which the second and third days of training (MD-4 and MD-3) consistently produced the greatest physiological and biomechanical loads, with the training session closest to the MD producing the lowest values (MD+1 and MD-2). This structure is in general agreement with other studies which have reported higher training load (TL) in the middle of the microcycle followed by a reduction in TL closer to MD (Trewin 2017; Malone et al. 2015; Akenhead et al. 2016; Scott et al. 2016; Owen et al. 2017; Martín-García et al. 2018). This periodization seems to be a preferred strategy of taper to recover from accumulated fatigue and promote readiness to perform. Such strategy would allow that the TL during the microcycle be adjusted according to conditioning demands and fatigue-recovery status, increasing chances to improve performance, without increased injury risk. Regarding injury rate, the team experienced 17 injuries across the whole season ((non-contact injuries=11, (Type: 7 joint/ligament, 3 muscle ,and 1 tendon injury), contact injuries=6 (Type: 4 joint/ligament and 1 fracture bone)). The rate was 1.9 injuries/1000 hours of exposure (training sessions= 1.4 injuries/1000 h. of exposure; Match=4.4 injuries/1000 h. of exposure). These data showed an injury incidence lower in comparison to the only previous study with a Spanish first division female football club, reporting 6.3 injuries/1000 h. of exposure (training sessions= 3.4 injuries/1000 h. of exposure; Match=22.5 injuries/1000 h. of exposure) (Larruskain et al., 2018).

Of note, although the microcycle structure observed in this study was repeated in a weekly basis, the EL and the IL showed a coefficient of variation of ~14-99% and ~12-55%, respectively (Table 1). These variations are likely due to different performance objectives placed across the various seasonal phases. Whilst these periodisation observations may be of general interest, they are to a great extent determined by coaching strategies and preferences. Considering that the results of this study relate to a single coach, these seasonal variations have at most a descriptive role, and further investigation would be required to gain a better understanding of potential moderators affecting observed variations and its implications.

When total relative distance and HSRD (>15 km.h^{-1}) were compared between MD-4 and MD-3, slightly lower values were noted on MD-4 (Figure 1A). Nonetheless, the players achieved greater RPE and sRPE on MD-4 compared to MD-3 (Figure 1C and 1D, respectively). The higher biomechanical loads (e.g. greater number of AC1) during MD-4 compared to MD-3 (Figure 1B) may explain such observation. Indeed, on MD-4, the coaches usually planned tactical exercises in reduced spaces, including small and medium-sided games. On MD-3, although tactical exercises were introduced, larger spaces were used, including medium and large-sided games. As seen in previous studies, biomechanical load is greater in small and medium-sided games than in large sided or full-pitch games (Giménez et al., 2018). The requirement to perform a higher volume of explosive eccentric actions such as changes of direction, accelerations and decelerations, seems particularly damaging to the muscle and induce higher neuromuscular fatigue (Silva et al., 2014), potentially leading toward greater perceived exertion in spite reduced total relative distance covered and HSRD.

Regarding playing positions, significant differences were noted between playing positions in the EL and IL during MD. In general, CB and WM showed the lowest loads, while CM and AT showed the highest loads during MD (Figure 1). Specifically, on MD, the CB achieved lower HSRD, RPE and sRPE, followed by the WM. On the other side of the load spectrum, the AT and CM showed greater loads. Moreover, although no significantly different, as depicted in Figure 1B, on MD, the CM and AT showed greater AC1 (ES= 0.62 to 2.52 and 1.00 to 2.30, respectively) compared to the rest of field positions. However, the analysis of positional differences during training sessions did not reflected the well-established positional differences observed during MD in this study, or in the literature (Martín-García et al., 2018). These data are consistent with the findings of Akenhead et al. (2016) who reported that male CM covered greater total distances compared to other field positions on MD, but distances covered at high-speed did not differ between positions during training sessions. Moreover, Gaudino et al. (2015) and Malone et al. (2015) reported only small differences between playing positions in professional male soccer players during training sessions.

Although no significant differences were noted between playing positions in training days, as depicted in Figure 1A, the CB and WM showed lower HSRD (i.e., >15 km·h) compared to other field positions on MD+1 (*ES* = 0.27 to 0.46 and 0.46 to 0.71, respectively), MD-4 (*ES* = 0.36 to 0.80 and 0.73 to 1.02, respectively), and MD-2 (*ES* = 0.24 to 0.46 and 0.45 to 0.65, respectively). Moreover, the CM performed greater number of total accelerations and decelerations compared to other field positions on MD+1 (*ES* = 0.22 to 0.42), MD-3 (*ES* = 0.42 to 0.63), and MD-2 (*ES* = 0.29 to 0.70). Furthermore, on MD-4, the AT had a greater number of total accelerations than CB, WB and WM (*ES* = 1.06, 0.45 and 0.97, respectively). Therefore, despite no significant positional differences in training days, meaningful differences were noted, potentially with a practical significance. Of note, the differences between playing positions on MD and during training sessions showed a pattern with lower loads in CB and WM, and greater loads in CM and AT. The frequent use of small-sided games by the female players in this study may have contributed to such findings, were players automatically assumed similar roles during training as per their player position in a match. That means that small-sided games (used in 50% of all training sessions in this study) may well be a suitable means to delivering player position-specific loads.

Although valuable information is provided in the current study, with new insights regarding the EL and IL during the competitive season in professional female soccer players according to their playing position, including training and competition loads, some potential limitations may be considered when interpreting current findings. First, this study was conducted in a professional soccer club, with 18 female soccer players. Therefore, generalization of current findings to other teams (e.g, amateur) should be conducted with caution. Nonetheless, current results may be valid for soccer teams using similar weekly schedules, such as per elite female soccer teams across Europe. Another potential limitation relates to the lack of quantification of weekly off-pitch training, such as strength and conditioning sessions in the gym. Additionally, due to logistical reasons, the warm-up loads prior to matches were not included in the current study, although they were included for training days. This may have caused a slight bias towards overestimation of loads in training sessions. However, considering that current results shown significantly greater loads during MD compared to training sessions, differences in loads between training sessions and matches may even be greater than those presented in this study.

Practical application

A critical aim for coaching staff is to design training programs, which expose the elite female soccer player to an appropriate training load prior to and after a competitive demand, particularly on the long-term (i.e., competitive season), in order to optimize performance, recover from fatigue, and avoid injury. Current results offer novel information for athletes and practitioners in order to achieve such aim. Particularly, we observed a need to implement differential training modes according to player's position in the field, particularly when competition loads are taken into consideration. In addition, our findings offer information to guide individualized position-specific training during the week along a professional competitive season. Moreover, considering the greater loads during MD compared to training sessions (even when compared against the training sessions with the highest loads [MD-4 and MD-3]), it might be necessary among elite female soccer players to add supplementary individualized training during the week. However, players usually has a congested schedule, making additional training sessions (or longer training sessions) during the week logistically unviable. In this context, incorporating differential training modes (i.e., time-efficient) may help to cope with observed differences between training and competition loads. This may be achieved by the introduction of high-speed straight runs, running involving directional changes, repeated short-medium-large sprint ability, time spent in game-based situations, with modifications of pitch dimensions. Such changes may aid to ensure playing position specific physiological and neuromuscular readiness. Of note, such modifications need adequate monitoring of players IL and EL, in order to optimize player's physical fitness readiness before a match, allow adequate recovery after a match, and avoid injury and overtraining. Moreover, although soccer-specific (e.g., technical drills, tactical drills, SSG) and position-specific loads are needed, it is important to consider such loads in a well-rounded long-term training program, incorporating strength and conditioning sessions (e.g., resistance training, plyometrics), and injury prevention drills (e.g., control motor exercises), particularly among female soccer players who may be at greater risk of injuries (Crossley et al., 2020).

Conclusion

The EL and the IL among professional female soccer players during the competitive season are greater during MD compared to training sessions, even against those training sessions with the greater EL and IL (i.e., MD-4 and MD-3). The training sessions MD+1 and MD-2 showed the lowest EL and IL values, potentially acting as taper-recovery training sessions. During MD, significant differences in EL and IL were noted between playing positions, although not during training sessions. These findings could have potential implications for practitioners when designing/prescribing optimal weekly training loads in elite female soccer players during the competitive season.

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Declaration of interest statement

The authors declare no conflict of interest with the finding reported in this study.

References

Akenhead, R., Harley, J. A., & Tweddle, S. P. (2016). Examining the external training load of an english premier league football team with special reference to acceleration. *Journal of Strength and Conditioning Research*, *30*(9), 2424–2432. https://doi.org/10.1519/JSC.0000000000001343

Anderson, L., Orme, P., Di Michele, R., Close, G. L., Milsom, J., Morgans, R., Drust, B., & Morton, J. P. (2016). Quantification of seasonal-long physical load in soccer players with different starting status from the English premier league: Implications for maintaining squad physical fitness. *International Journal of Sports Physiology and Performance*, *11*(8), 1038–1046. https://doi.org/10.1123/ijspp.2015-0672

Bartlett, J. D., O’Connor, F., Pitchford, N., Torres-Ronda, L., & Robertson, S. J. (2017). Relationships between internal and external training load in team-sport athletes: Evidence for an individualized approach. *International Journal of Sports Physiology and Performance*, *12*(2), 230–234. https://doi.org/10.1123/ijspp.2015-0791

Batterham, A. M., & Hopkins, W. G. (2006). Making meaningful inferences about magnitudes. *International Journal of Sports Physiology and Performance, 1*(1), 50–57. https://doi.org/10.1123/ijspp.1.1.50

Colby, M. J., Dawson, B., Heasman, J., Rogalski, B., & Gabbett, T. J. (2014). Accelerometer and GPS-derived running loads and injury risk in elite Australian footballers. *Journal of Strength and Conditioning Research*, *28*(8), 2244–2252. https://doi.org/10.1519/JSC.0000000000000362

Crossley, K. M., Patterson, B. E., Culvenor, A. G., Bruder, A. M., Mosler, A. B., & Mentiplay, B. F. (2020). Making football safer for women: a systematic review and meta-analysis of injury prevention programmes in 11 773 female football (soccer) players. *British Journal of Sports Medicine*, bjsports-2019-101587. https://doi.org/10.1136/bjsports-2019-101587

Datson, N., Drust, B., Weston, M., Jarman, I. H., Lisboa, P. J., & Gregson, W. (2017). Match Physical Performance of Elite Female Soccer Players during International Competition. *Journal of Strength and Conditioning Research*, *31*(9), 2379–2387. https://doi.org/10.1519/JSC.0000000000001575

Datson, N., Hulton, A., Andersson, H., Lewis, T., Weston, M., Drust, B., & Gregson, W. (2014). Applied physiology of female soccer: an update. *Sports Medicine*, *44*(9), 1225–1240. https://doi.org/10.1007/s40279-014-0199-1

Faude, O., Koch, T., & Meyer, T. (2012). Straight sprinting is the most frequent action in goal situations in professional football. *Journal of Sports Sciences*, *30*(7), 625–631. https://doi.org/10.1080/02640414.2012.665940

Foster, C., Florhaug, J. A., Franklin, J., Gottschall, L., Hrovatin, L. A., Parker, S., Doleshal, P., & Dodge, C. (2001). A New Approach to Monitoring Exercise Training. *Journal of Strength and Conditioning Research*, *15*(1), 109–115. https://doi.org/10.1519/1533-4287(2001)015<0109:ANATME>2.0.CO;2

Giménez, J. V, Del-Coso, J., Leicht, A. S., & Gomez, M.-Á. (2018). Comparison of the movement patterns between small- and large-sided game training and competition in professional soccer players. *The Journal of Sports Medicine and Physical Fitness*, *58*(10), 1383–1389. https://doi.org/10.23736/S0022-4707.17.07343-1

Gomez-Piriz, P. T., Jiménez-Reyes, P., & Ruiz-Ruiz, C. (2011). Relation between total body load and session rating of perceived exertion in professional soccer players. *Journal of Strength and Conditioning Research*, *25*(8), 2100–2103. https://doi.org/10.1519/JSC.0b013e3181fb4587

Hulin, B. T., Gabbett, T. J., Lawson, D. W., Caputi, P., & Sampson, J. A. (2016). The acute: Chronic workload ratio predicts injury: High chronic workload may decrease injury risk in elite rugby league players. In *British Journal of Sports Medicine* (Vol. 50, Issue 4, pp. 231–236). https://doi.org/10.1136/bjsports-2015-094817

Impellizzeri, F. M., Rampinini, E., Coutts, A. J., Sassi, A., & Marcora, S. M. (2004). Use of RPE-based training load in soccer. *Medicine and Science in Sports and Exercise*, *36*(6), 1042–1047. https://doi.org/10.1249/01.MSS.0000128199.23901.2F

Jaspers, A., Brink, M. S., Probst, S. G. M., Frencken, W. G. P., & Helsen, W. F. (2017). Relationships Between Training Load Indicators and Training Outcomes in Professional Soccer. *Sports Medicine*, *47*(3), 533–544. https://doi.org/10.1007/s40279-016-0591-0

Krustrup, P., Mohr, M., Ellingsgaard, H., & Bangsbo, J. (2005). Physical demands during an elite female soccer game: Importance of training status. *Medicine and Science in Sports and Exercise*, *37*(7), 1242–1248. https://doi.org/10.1249/01.mss.0000170062.73981.94

Larruskain, J., Lekue, J. A., Diaz, N., Odriozola, A., & Gil, S. M. (2018). A comparison of injuries in elite male and female football players: A five-season prospective study. *Scandinavian Journal of Medicine and Science in Sports*, *28*(1), 237–245. https://doi.org/10.1111/sms.12860

Los Arcos, A., Mendez-Villanueva, A., & Martínez-Santos, R. (2017). In-season training periodization of professional soccer players. *Biology of Sport*, *34*(2), 149–155. https://doi.org/10.5114/biolsport.2017.64588

Lu, D., Howle, K., Waterson, A., Duncan, C., & Duffield, R. (2017). Workload profiles prior to injury in professional soccer players. *Science and Medicine in Football*, *1*(3), 237–243. https://doi.org/10.1080/24733938.2017.1339120

Malone, J. J., Di Michele, R., Morgans, R., Burgess, D., Morton, J. P., & Drust, B. (2015). Seasonal training-load quantification in elite English Premier League soccer players. *International Journal of Sports Physiology and Performance*, *10*(4), 489–497. https://doi.org/10.1123/ijspp.2014-0352

Martín-García, A., Gómez Díaz, A., Bradley, P. S., Morera, F., & Casamichana, D. (2018). Quantification of a Professional Football Team's External Load Using a Microcycle Structure. *Journal of Strength and Conditioning Research*, *32*(12), 1. https://doi.org/10.1519/JSC.0000000000002816

Mohr, M., Krustrup, P., Andersson, H., Kirkendal, D., & Bangsbo, J. (2008). Match activities of elite women soccer players at different performance levels. *Journal of Strength and Conditioning Research*, *22*(2), 341–349.

Owen, A. L., Djaoui, L., Newton, M., Malone, S., & Mendes, B. (2017). A contemporary multi-modal mechanical approach to training monitoring in elite professional soccer. *Science and Medicine in Football*, *1*(3), 216–221. https://doi.org/10.1080/24733938.2017.1334958

Ramos, G. P., Nakamura, F. y., Penna, eduardo m., Wilke, C. F., Pereira, L. a., Loturco, I., Capelli, L., Mahseredjian, F., Silami-Garcia, E., & Coimbra, C. c. (2019). Activity Profiles in U17, U20, and Senior Women's Brazilian National Soccer Teams During International Competitions. *Journal of Strength and Conditioning Research*, *33*(12), 3414–3422. https://doi.org/10.1519/JSC.0000000000002170

Scott, M. T. U., Scott, T. J., & Kelly, V. G. (2016). The validity and reliability of global positioning systems in team sport: A brief review. *Journal of Strength and Conditioning Research*, *30*(5), 1470–1490. https://doi.org/10.1519/JSC.0000000000001221

Silva, J. R., Rebelo, A., Marques, F., Pereira, L., Seabra, A., Ascensão, A., & Magalhães, J. (2014). Biochemical impact of soccer: an analysis of hormonal, muscle damage, and redox markers during the season. *Applied Physiology, Nutrition, and Metabolism*, *39*(4), 432–438. https://doi.org/10.1139/apnm-2013-0180

Stevens, T. G. A., de Ruiter, C. J., Twisk, J. W. R., Savelsbergh, G. J. P., & Beek, P. J. (2017). Quantification of in-season training load relative to match load in professional

Dutch Eredivisie football players. *Science and Medicine in Football*, *1*(2), 117–125. https://doi.org/10.1080/24733938.2017.1282163

Trewin, J. S. W. (n.d.). *2017. Match-running performance of elite female soccer players: The factors affecting performance and training applications (Doctoral Thesis). University of Victoria.* [University of Victoria]. Retrieved May 10, 2018, from http://aut.researchgateway.ac.nz/bitstream/handle/10292/11519/TrewinJ.pdf?sequence=4&isAllowed=y

Vanrenterghem, J., Nedergaard, N. J., Robinson, M. A., & Drust, B. (2017). Training Load Monitoring in Team Sports: A Novel Framework Separating Physiological and Biomechanical Load-Adaptation Pathways. *Sports Medicine*, *47*(11), 2135–2142. https://doi.org/10.1007/s40279-017-0714-2

Vescovi, J. D., & Favero, T. G. (2014). Motion Characteristics of Women's College Soccer Matches: Female Athletes in Motion (FAIM) Study. *International Journal of Sports Physiology and Performance*, *9*(3, SI), 405–414. https://doi.org/10.1123/IJSPP.2013-0526

Table 1. Average weekly external and internal loads during training sessions and matches in professional female soccer players during the competitive season.

	MD	MD+1 (recovery session)		MD-4 (condition and tactical session)		MD-3 (condition and tactical session)		MD-2 (skills and strategy exercise session)	
	Mean±SD	Mean±SD	ES	Mean±SD	ES	Mean±SD	ES	Mean±SD	ES
Number of session (N)	94	82		94		90		92	
Duration (min)	95±6	52±20*	2.59-3.48	82±11*#	0.65-2.77	78±17*#	0.98-1.76	70±18* # † ‡	1.23-3.14
External Physiological Load									
Total distance covered (m)	9040±938	2496±1639*	4.40-6.48	4832±861*#	4.14-7.07	4975±1319*#†	2.79-4.41	3025±1221* † ‡	4.56-6.03
Total distance covered relative to MD (%)		26.1±17.4*	3.70-4.49	53.4±8.7*#	4.29-4.94	53.4±14.0*#	2.04-3.53	32.7±13.3* † ‡	3.65-5.09
Relative distance covered (m·min-1)	95±9	44±16*	3.7-4.6	59±10*#	4.3-4.94	65±14*#†	2.0-3.5	43±15* † ‡	3.7-5.1
Relative distance covered relative to MD (%)		45.2±16.96*	3.40-4.22	61.6±9.2*#	3.81-4.72	68.1±15.2*#†	1.88-2.11	44.7±15.2* † ‡	3.54-4.24
HSRD covered (m)	1108±294	170±214*	4.08-5.87	383±242*#	3.95-6.62	494±248*#	2.70-4.13	172±121* # †	4.25-5.42
HSRD covered relative to MD (%)		14.6±19.4*	3.59-4.58	33.8±20.5*#	3.01-4.74	44.1±25.6*#†	3.05-3.70	35.2±14.2‡	3.62-4.72
Relative HRSD covered (m·min-1)	12.1±2.4	3.4±5.2*	3.4-5.2	4.8±3.1*#	2.4-4.0	6.6±2.9*#†	2.0-5.5	2.6±1.8* † ‡	3.8-8.2
Relative HSRD relative to MD (%)		14.8±19.4*	3.06-4.55	33.8±20.5*#	1.96-4.31	44.1±22.6*#†	1.19-2.97	15.4±10.7* † ‡	3.44-5.81
External Biomechanical Load									
Total number of accelerations (N)	255±40	70±56*	3.62-4.72	144±39*#	2.84-3.78	132±40*#	2.78-4.21	73±40* † ‡	4.65-5.42
Accelerations relative to MD (%)		35±33*	3.4-5.1	74±52*#	2.4-4.4	66±44*#	2.4-4.6	37±31* † ‡	3.3-5.5
Total number of decelerations (N)	78±16	17±17*	3.29-6.43	38±16*#	1.94-3.66	38±13*#	2.38-4.74	20±13* † ‡	3.52-6.30
Decelerations relative to MD (%)		21±22*	2.6-3.9	50±23*#	1.8-3.1	50±18*#	1.9-3.9	26±18* † ‡	3.1-5.1
Body Load (au)	170±49	54±52*	1.31-5.11	89±41*#	0.96-3.67	90±53*#	0.78-2.91	55±38* † ‡	1.78-5.40
Internal Load									
RPE	8.4±0.8	3.6±1.6*	3.3-4.8	6.2±1.0*#	2.0-2.8	5.0±1.0*#†	2.5-5.1	3.1±1.1* † ‡	4.7-7.9
sRPE	792±103	167±134*	3.9-6.1	579±139*#	1.5-2.7	444±170*#†	2.4-5.1	222±102* † ‡	3.6-7.2

Date as mean ± standard deviation (SD). MD: match day (warm-up excluded). Symbols indicate significant difference ($p<0.05$) from MD (*), MD+1 (#), MD-4 (†), and MD-3 (‡); ES: effect size.

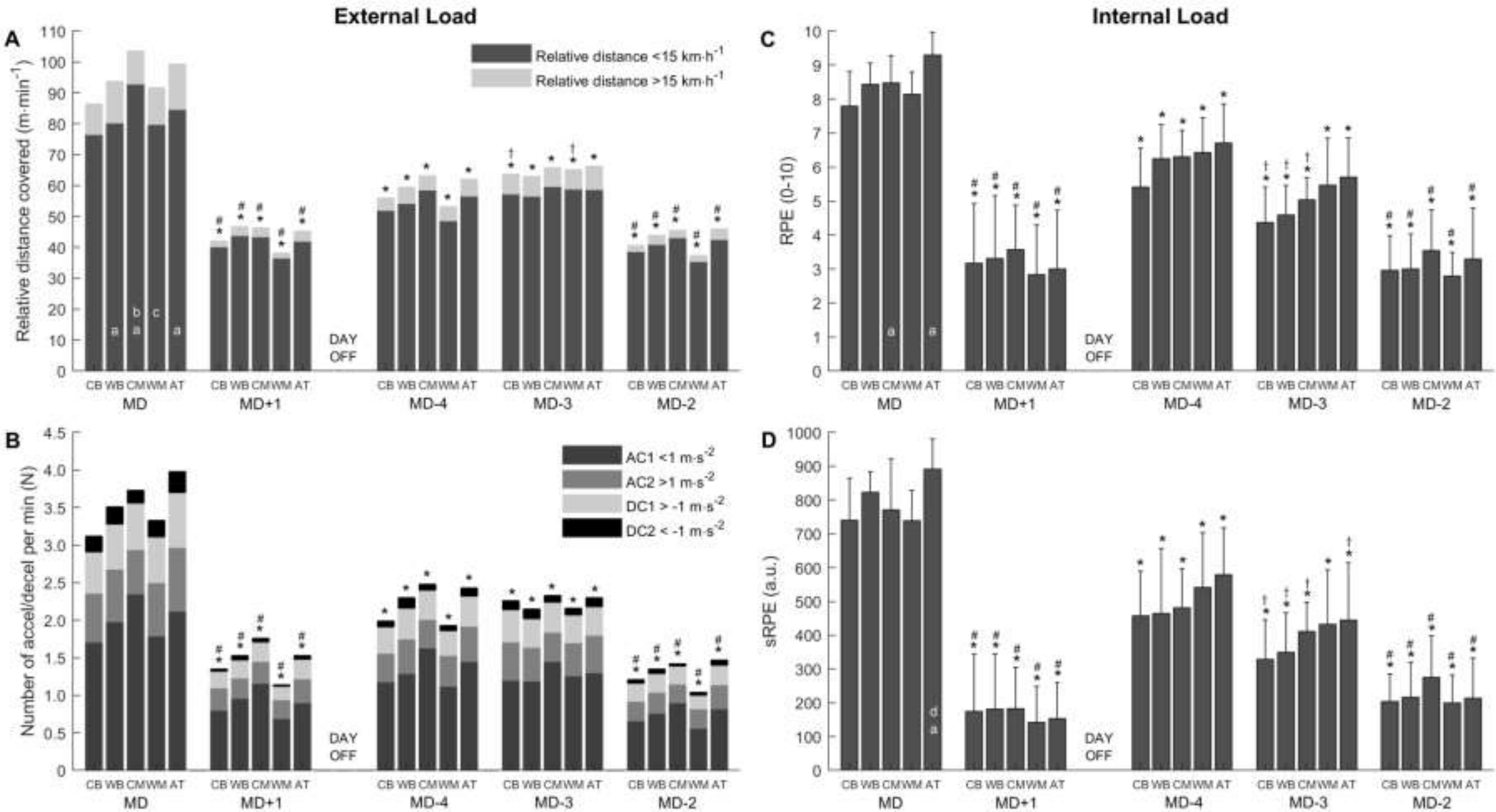

Figure 1. Training and match loads in professional female soccer players during a competitive season.

A) Total distance travelled (relative to total session time) at running speeds below or above 15 km·h^{-1}; **B)** Number (relative to total session time) of accelerations (accel) and decelerations (decal) below (AC1 and DC2, respectively) or above (AC2 and DC1, respectively) 1 m·s^{-2}; **C)** Rate of perceived exertion (RPE); **D)** session-RPE (sRPE; in arbitrary units [a.u.]).

CB: central backs; **WB**: wide backs; **CM**: central midfielders; **WM**: wide midfielders; **AT**: attackers.

MD: match day (on Sunday); **MD+1**: recovery session (on Monday); **Day off**: on Tuesday; **MD-4**: conditioning and tactical session (on Wednesday); **MD-3**: conditioning and tactical session (on Thursday); **MD-2**: skills and strategy exercises (on Friday).

*: denotes significant ($p<0.05$) difference from MD; #: denotes significant ($p<0.05$) difference from both MD-4 and MD-3; †: denotes significant ($p<0.05$) difference from MD-4; [a, b, c, d]: denotes significant difference ($p<0.05$) from CB, WB, CM, and WM, respectively.