©Journal of Sports Science and Medicine (2019) **18,** 73-81
http://www.jssm.org

Research article

The Use of GPS Analysis to Quantify the Internal and External Match Demands of Semi-Elite Level Female Soccer Players during a Tournament

Anita Strauss [1,2]✉, Martinique Sparks [2] and Cindy Pienaar [2]
[1] Department of Sport, Rehabilitation & Dental Science, Tshwane University of Technology, Pretoria, South Africa
[2] Physical Activity, Sport and Recreation (PhASRec), North-West University, Potchefstroom, South Africa

Abstract
The purpose of this study was to make use of global positioning system technology to quantify the internal and external match demands of sub-elite female soccer players. Secondly, the study aims to describe the magnitude of change of these variables within and between matches over the course of a tournament to determine the effect of player fatigue. Thirty sub-elite female soccer players were assessed throughout a local tournament. Differences in match demands within and between matches were assessed using percent difference, effect size and 90% confidence intervals. One-way ANOVA was used to compare differences in the match demands and running intensities among playing positions and Bonferroni corrections were used to determine differences where significant effects of position were observed. A paired sample t-test in conjunction with the Cohen effect size was used to compare changes in match performance. Total distance covered averaged 5917 m. Midfielders covered the greatest absolute and relative total distances, and achieved the highest low-intensity activity and player load per minute of play. Defenders covered significantly ($p \leq 0.05$) less relative distance and low-intensity activity per minute of play compared to midfielders. Forwards covered the greatest distance at high-intensity, while the greatest percentage of time at high-intensity heart rate was measured among the defenders. Within match comparisons revealed that player load decreased significantly ($p \leq 0.05$) in the second half (ES: 0.4). Relative distance, low-intensity activity and high-intensity activity also decreased in the second half with possibly trivial to likely small changes. Small to large differences in variables were observed throughout the tournament. The biggest magnitude of change was seen with a large decrease (ES: -1.2) in relative distance covered between match 2 and 5. Despite generally small reductions in performance measures, there is evidence that accumulated fatigue throughout a multi-day tournament would affect performance negatively.

Key words: GPS, heart rate, HIA, match analysis, player load.

Introduction

The soccer milieu has seen a considerable increase in female soccer players participating in international competitions, professional and recreational leagues (Martínez-Lagunas et al., 2014). Female players now have the opportunity to train and compete in professional settings, which gave rise to an increase in the performance expectations placed upon players, and subsequently a need for specific scientific research that could assist to enhance performance (Martínez-Lagunas et al., 2014). The successful evaluation of the physical demands placed upon soccer players requires accurate assessment of both internal and external match demands (Gaudino et al., 2015). Wearable technology such as global positioning system (GPS) devices simultaneously used with heart rate (HR) monitoring, are commonly used in elite sport to monitor the internal and external loads of athletes in order to assess physiological and movement demands (Barbero Álvarez et al., 2008; Cunniffe et al., 2009). The use of GPS technology further allows for direct measurement of a player's movement during a match as opposed to the subjective determination of movement by an observer as required with video analysis (Varley et al., 2014).

Movement activities in soccer are generally classified according to intensity, determined by the speed of the action (Carling et al., 2008). Match analysis of locomotor activities performed over different velocity zones (especially at high-intensity) attracts more attention in literature, since it reflects the physical demands of competition (Ramos et al., 2017). Although a large part of a match consists of walking or jogging, it is important to determine the pattern of high-intensity work performed (Hewitt et al., 2014), as high-intensity movements have been shown to vary between different levels of participation (Mara et al., 2017). Studies using GPS technology found that elite and sub-elite female soccer players cover a total distance of around 8–11 km during a match, ranging between 108–119 and 96–107 metres per minute of play (m/min) for elite and sub-elite players respectively (Andersson et al., 2010; Bradley et al., 2014; Hewitt et al., 2014; Mohr et al., 2008; Ramos et al., 2017; Trewin et al., 2018; Vescovi and Favero, 2014), while sprinting and HIR constitutes 8–12% of the total distance covered (Andersson et al., 2010; Bradley et al., 2009; Gabbett and Mulvey, 2008; Krustrup et al., 2005; Mohr et al., 2008). Midfielders tend to cover the greatest total distance during a match and cover more distance at HIR and sprinting, while defenders cover the shortest total distance as well as distances at HIR and sprinting (Andersson et al., 2010; Hewitt et al., 2014). However, the distance covered at different running speeds should not be the only consideration when evaluating a player's total work load (Dalen et al., 2016). Player load is a representation of total body load expressed in arbitrary units and involves the measurement of three dimensional body movements with triaxial accelerometers (Barron et al., 2014; Dalen et al., 2016). Certain high-intensity soccer-specific movements classified as low-speed movements such as jumping, tackling, collisions, accelerations, decelerations, passing, shooting, sideways and backward running, have been neglected, leading to an

Received: 24 July 2018 / Accepted: 31 October 2018 / Published (online): 11 February 2019

underestimation of physical stress, even though it can place high physical strain on players (Dalen et al., 2016). Player load is also found to differ between playing positions in male soccer, with midfielders achieving a higher player load compared to forwards and defenders (Barron et al., 2014; Dalen et al., 2016). To the author's knowledge no data is available on female soccer examining player load according to playing positions.

Internal load is perceived as a player's response to an external physical stimulus (Scott et al., 2013). Heart rate measurement is often used as an indirect measure of exercise intensity and used to examine the internal load of players during training or competition (Datson et al., 2014; Ohlsson et al., 2015). A method commonly used to quantify internal match load is to describe the amount of time spent in different intensity zones based on the percentage of maximum HR (HR_{max}) (Bendiksen et al., 2013; Ohlsson et al., 2015). Average HR and peak HR values of 84–89% and 98–100% of HR_{max} respectively have been reported for female soccer players during matches (Andersson et al., 2010; Krustrup et al., 2010; Ohlsson et al., 2015). This is an indication that female players experience a high aerobic load throughout a match with periods of near-maximal values (Krustrup et al., 2005). Significant differences in HR recordings between the first and second half are also evident (Ohlsson et al., 2015). Peak and mean HR recorded during the first half seems to be significantly higher than the second half (Ohlsson et al., 2015; Rampinini et al., 2008). Further analysis showed that a significant reduction occurred in the time spent in the intensity zone above 95% (Ohlsson et al., 2015).

Apart from performance assessment during individual matches, the ability of female soccer players to repeat high-intensity efforts on numerous occasions over several days along with the changes in movement patterns over the course of a tournament, have not been examined previously. It is believed that the physiological stress experienced by players result in fatigue that leads to a decrease in performance (Marqués-Jiménez et al., 2017). In order to perform optimally, appropriate recovery interventions in competitive tournaments and between matches are important (Andersson et al., 2008). It is also claimed that players regulate exercise intensity throughout matches to ensure sufficient physiological reserves to complete that match (Edwards and Noakes, 2009). Pacing strategies utilised throughout a match therefore remains a contextual factor to consider in soccer.

To date, limited literature exists on the position-specific match-related locomotor categories, player load profiles and internal match demands of female soccer players. Also, it has yet to be elucidated what affect a week-long tournament has on running intensities and movement patterns. A detailed analysis of the internal and external load within a match and throughout a tournament gives a greater insight into the physical demands of female soccer and the requirements over the duration of such a tournament. Highlighting meaningful performance characteristics associated with the demands of female soccer through match analysis is essential to provide information to coaches and conditioning specialists towards prescribing and implementing sport-specific conditioning programmes that replicate the physical demands of competition and adjusting physical preparation to the precise requirements of each position. The primary aim of this study were to determine the internal and external match demands of sub-elite female soccer players during a tournament. The secondary aim was to describe the magnitude of change of these variables within and between matches over the course of a tournament to determine the effect of player fatigue. The hypothesis of the study is that the internal and external match demands of sub-elite female soccer players will differ significantly ($p \leq 0.05$) within and between matches in a tournament.

Methods

Experimental approach to the problem

An observational study was conducted to compare the internal and external match demands of sub-elite female soccer players according to playing positions and the role of fatigue during ten official matches of a club championship. A clear distinction between elite and sub-elite athletes is not defined in literature. For the purpose of this article, elite players are regarded as players competing on national level and higher divisions, while sub-elite level generally refer to players competing on club, college or university level. Each team was monitored for five consecutive matches during the course of a week-long tournament. The matches were played on a standardised soccer field and consisted of two 35 minute halves. Comparisons were made based on different GPS-derived variables, including total distance, distances covered in different velocity zones, high-intensity activities and corresponding heart rates, work rate and player load.

Subjects

Thirty sub-elite female soccer players (age: 22.8 ± 2.4 years; height: 1.59 ± 0.05 m; body mass: 54.1 ± 6.1 kg) representing two university teams participated in the study. Data of players who completed full matches were retained for analysis. Players were categorised according to playing position, namely forwards (FW), midfielders (MF) and defenders (DF). Prior to data collection, ethical approval was obtained from the university's Health Research Ethics Committee (NWU-00055-15-A1). Research was conducted according to the declaration of Helsinki. Subjects were informed of the potential benefits and risks of the investigation prior to signing an institutionally approved informed consent document to participate in the study.

Procedures

Match analysis: Only the activity profiles of the starting line-up were recorded during all matches, providing a total of 84 individual match files. Goalkeepers were excluded from the analysis. Matches were analysed with GPS units sampling at 10 Hz and equipped with 100 Hz accelerometer (MinimaxX S4 V4.0, Catapult Innovations, Victoria, Australia). GPS units were fitted to the upper back of each player using a harness. Units were turned on 10 minutes before each match. For a movement to be recorded as an effort, players had to maintain that specific velocity for at least 0.5 sec. Locomotor activities were defined as previously reported for female soccer players (Bradley and Vescovi, 2015; Vescovi, 2014; Vescovi and Favero, 2014): standing and walking (0.0–1.6 m/s), jogging (1.7–2.2 m/s), low-intensity running (2.3–3.3 m/s), moderate-intensity running (3.4–4.3 m/s), high-intensity running (4.4–5.6 m/s) and sprinting (>5.6 m/s). Data were normalised to distance per minute played (m/min) to account for differences in total playing time and in match stoppages. For statistical analysis, data were categorised into total distance (m), relative distance (m/min), low-intensity activity per minute (LIA/min) (consisting of standing/walking, jogging and low-intensity running), moderate-intensity running (MIR), high-intensity activity per minute (HIA/min) (consisting of high-intensity running and sprinting), player load per minute (PL/min) and high-intensity heart rate per minute (HIHR/min). Player load was determined by the software using the following formula:

$$(a_{y1}-a_{y-1})^2 + (a_{x1}-a_{x-1})^2 + (a_{z1}-a_{z-1})^2$$

where a_y=anteroposterior acceleration, a_x=mediolateral acceleration, and a_y=vertical acceleration

Horizontal dilution of precision (HDOP) indicates accuracy of GPS in a horizontal plane and optimum satellite availability. During the tournament the average HDOP was 1.06. Data recorded on GPS units were downloaded onto a PC and analysed using the Logan Plus V4.7.1 software (Catapult Sports, Victoria, Australia). An intelligent motion filter incorporated within the GPS unit and software was used to exclude non-game activity, by considering stoppages in play such as during half-time and at the end of play. The raw data were also further divided into first half and second half files. GPS Doppler data were used during analysis of the GPS-related variables. The validity and reliability of the GPS units have been reported previously (Varley et al., 2012).

Heart rate monitoring: Heart rate (HR) was recorded individually through a Fix Polar Heart Rate Transmitter Belt (Polar Electro, Kempele, Finland) at five second intervals during the matches. The transmitter belts were fitted to each player before the match. HR_{max} was defined as each individual's maximum HR collected during the matches, which were then used for match analysis. Heart rate values were divided into six intensity zones: <60%, 60–75%, 75–85%, 85–90%m 90–95%, and >95% (Bangsbo, 1993). High-intensity exercise, described as HIHR in this study, was defined as exercise intensity with a HR above 90% of HR_{max} (Castagna et al., 2011). The percentage of time spent in HR zones was used for analysis. Before data analysis commenced, players were excluded if they had missing data in cases where the heart rate monitor did not record any data, possibly due to the HR belt which moved during play and was not positioned appropriately for HR recording.

Statistical analysis

Variables were log transformed to reduce bias due to non-uniformity of error and analysed using the effect size (ES) statistics with 90% confidence intervals (CI) and percent difference to determine the magnitude of effects using a custom spreadsheet (Hopkins, 2003). Magnitude-based inferences on differences within and between matches were made by standardising differences using the between-subject SD. Descriptive statistics are presented as mean ± standard deviation and were used to characterise movement patterns. Data are expressed relative to game time played (per minute) to account for variations in playing time from match-to-match. Differences in the match demands and running intensities among playing positions were compared using one-way ANOVA. Where significant effects of position were observed, Bonferroni corrections were used to determine differences in positions. A paired sample t-test in conjunction with the Cohen effect size was used to compare changes in match performance between the first and second halves and between individual matches. Magnitudes of standardised effects were assessed as 0–0.2 trivial, 0.2–0.6 small, 0.6–1.2 moderate, 1.2–2.0 large, and >2.0 very large (Batterham and Hopkins, 2006). The effect was reported as unclear when the CI of the standardised difference crossed the threshold for both substantially positive (0.2) and negative (-0.2) values. The quantitative chances of finding differences were assessed qualitatively as follows: < 1%, almost certainly not; 1–5%, very unlikely; 5–25%, unlikely; 25–75%, possible; 75–95%, likely; 95–99%, very likely; > 99%, almost certain. The level of statistical significance was set at $p \leq 0.05$.

Results

Table 1 displays the match demands with relevance to playing positions. Midfielders covered the greatest total distance (6065 m), followed by forwards (5847 m). Defenders covered the shortest total distance (5567 m) throughout the matches. Midfielders covered significantly ($p \leq 0.05$) greater relative total distance (84.4 m/min) and LIA (72.2 m/min) per minute of play compared to defenders. Forwards performed more HIA (4.9 m/min) per minute of play compared to the other playing positions, although this difference was not significant. Midfielders achieved a higher player load (9.7 PL/min) compared to both forwards (8.3 PL/min) and defenders (8.6 PL/min). Furthermore, defenders spent the greatest amount of time (13.3%) in the HIHR zone, and forwards the least (9.7%).

Mean HR recorded during the matches was 159 beats per minute (bpm), which corresponded to 81% of HR_{max} being 197 bpm. Mean HR was higher (ES: 0.3) during the first compared to the second half (162 vs 157 bpm), corresponding to 82% and 80% of HR_{max} respectively. Players spent the greatest amount of time in the 75–85% of HR_{max} zone (Figure 1), and spent a combined total of 13% of the total time in the HIHR zones of 90–100% of HR_{max}.

Differences in match demands between the first and second half are presented in Table 2. Although player load decreased significantly ($p \leq 0.05$) from the first to the

Table 1. Match demands according to positional groups. Data are displayed as mean ± SD (and 90% CI).

Variable	Forwards	Midfielders	Defenders
Total distance	5847 ± 739 (5510–6183)	6065 ± 880 (5764–6366)	5567 ± 818 (5333–5801)
PL/min	8.3 ± 0.9 (7.9–8.7)	9.7 ± 1.9 (9.0–10.3)	8.6 ± 1.6 (8.1–9.1)
m/min	80.4 ± 9.8 (75.9–84.9)	84.4 ± 12.5 (80.1–88.6)	76.9 ± 10.7 (73.8–79.9)*
LIA/min	68.9 ± 9.3 (64.6–73.1)	72.2 ± 10.0 (69.3–76.1)	66.7 ± 8.0 (64.4–69.0)*
HIA/min	4.9 ± 1.9 (4.0–5.7)	4.7 ± 3.1 (3.6–5.7)	4.7 ± 2.8 (3.9–5.4)
HIHR/min	9.7 ± 10.2 (5.1–14.4)	12.8 ± 17.1 (7.0–18.7)	13.3 ± 15.9 (8.8–17.8)

CI: Confidence interval; SD: Standard deviation; HIA/min: high-intensity activity per minute; HIHR/min: high-intensity heart rate per minute; LIA/min: low-intensity activity per minute; m/min: meterage per minute; PL/min: player load per minute. * Significantly different from Midfielders ($p \leq 0.05$) with a moderate effect size (ES: 0.8-1.0).

Table 2. Difference in match demands between first and second half (mean ± SD).

Variable	First half	Second half	*p*	Cohen d ± 90% CI	Practical outcome
PL/min	9.1 ± 1.6	8.5 ± 2.1	0.02*	0.4 (0.1–0.6)	Likely small
m/min	82.8 ± 11.7	76.4 ± 15.6	0.07	0.3 (0.0–0.5)	Possibly small
LIA/min	71.4 ± 9.3	66.0 ± 12.9	0.07	0.3 (0.0–0.5)	Possibly small
HIA/min	4.9 ± 3.1	4.6 ± 2.6	0.95	0.1 (-0.2–0.3)	Possibly trivial
HIHR/min	14.6 ± 17.3	10.3 ± 2.3	0.57	0.1 (-0.2–0.4)	Possibly trivial

CI: Confidence interval; SD: Standard deviation; HIA/min: high-intensity activity per minute; HIHR/min: high-intensity heart rate per minute; LIA/min: low-intensity activity per minute; m/min: meterage per minute; *p*: significance; PL/min: player load per minute. * Significantly different from first half ($p \leq 0.05$).

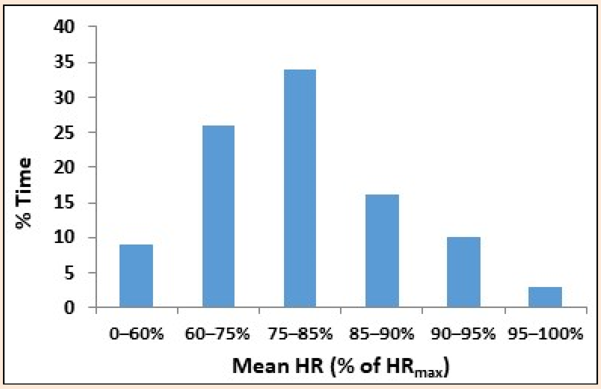

Figure 1. Percentage of time spent at the intensity zones of HR_{max} during sub-elite female soccer matches

second half, the effect was likely small. Similarly, all other match variables decreased during the second half, but none of these were statistically significant ($p > 0.05$) and displayed possibly trivial to small effect sizes.

Table 3 indicates the magnitude of change between matches over the course of the tournament. When comparing Match 1 with Match 2, 3, and 4, likely small to moderate positive changes were observed for PL, relative distance and LIA, while a positive change (likely moderate) for HIA was only observed from Match 1 to Match 2. Furthermore, with the exception of the possible moderate positive change observed for player load between Match 3 and 4, all the other changes observed for the remaining match comparisons were negative, and mostly ranged between small and moderate, although a probable large negative change was identified between Match 2 and 5 in terms of relative distance covered. Unclear changes were noticed between Match 2 versus Match 3 and 4, and Match 3 versus Match 4 for LIA, and also between Match 1 versus Match 3 and 4, and between Match 3 versus Match 4 and 5 for HIA. In terms of internal demands assessed, changes in time spent at HIHR ranged between trivial and small, and did not seem to follow a specific trend for increases or decreases observed.

Discussion

This is the first study to describe the match demands and movement profile of South African sub-elite female soccer matches. Unique to this study was the use of velocity zones specific for female field sports in the categorisation of locomotor characteristics (Vescovi and Favero, 2014) and to determine the influential role of fatigue within and throughout a tournament. The study also distinctly compared positional differences, adding to the limited studies conducted on sub-elite level, and broaden our knowledge on what is regarded as a gap in female soccer. The results of the study support the hypothesis that all the variables studied would show reductions during the course of a tournament over consecutive days. This was specifically apparent from the second to the last match of the tournament. Direct comparisons were limited due to shorter match periods used in the current study compared to other studies on female players. This was due to the design of the tournament whereby matches were played on consecutive days for a total of five days to determine the winner of the tournament. Also, studies reporting on the match-to-match comparisons throughout a female soccer tournament are scarce. Though, similar trends for positional differences during a match were noted in comparison with other studies on female players.

Table 3. **Magnitude of change (mean ± 90% CI) and effect sizes (90% CI) of match demands over the course of a soccer tournament. Chance that magnitude of change between two games is higher/no difference/lower (100/0/0).**

Variable		M1 v M2	M1 v M3	M1 v M4	M1 v M5	M2 v M3	M2 v M4	M2 v M5	M3 v M4	M2 v M5	M3 v M4
PL/min	% Diff	18.0±15.0	12.6±15.7	14.7±16.7	-7.1±33.7	-5.5±4.1	-2.7±5.3	-9.0±16.6	2.9±4.5	-5.5±16.1	-6.9±14.8
	ES and	.6	.4	.5	.3	-.3	-.2	-.5	.2	-.4	-.4
	90%CI	(.1−1.1)	(-.1−.9)	(-.1−1)	(-1.3 −.7)	(-.6 −-.1)	(-.5−.1)	(-1.4 −.3)	(-.1−.5)	(-1.3−.6)	(-1.3 −.4)
	QO.	90/9/1	77/20/3	81/16/2	21/25/54	0/18/82	3/57/40	8/17/75	45/53/1	16/23/61	10/21/69
m/min	% Diff	16.2±14.6	12.8±16.6	13.2±17.0	-8.5±35.4	-3.1±2.5	-3.2±3.6	-12.6±16.0	-1.5+3.5	-10.5±14.2	-8.3±14.4
	ES and	.7	.6	.6	-.4	-.3	-.3	-1.2	-.2	-1.1	-.6
	90%CI	(.1−1.4)	(-.2 −1.3)	(-.2 −1.4)	(-1.9 −1.0)	(-.5−-.1)	(-.6−0)	(-2.6−.1)	(-.5−.2)	(-2.4−.2)	(-1.6−.4)
	QO.	91/7/2	82/14/4	82/14/4	22/16/61	0/25/75	1/29/70	4/6/90	4/56/39	5/7/88	8/15/78
LIA/min	% Diff	12.6±13.4	11.4±15.1	13.4±15.1	-6.4±32.9	-0.7±2.7	-.3±3.0	-9.2±14.5	-.9±3.1	-9.5±12.7	-7.6±13.7
	ES and	.6	.5	.6	-.3	-.1	-.0	-1.0	-.1	-1.0	-.7
	90%CI	(-.−1.2)	(-.2 −1.3)	(-.1−1.3)	(-1.8−1.1)	(-.3 −.2)	(-.3−.3)	(-2.3−.4)	(-.4−.2)	(-2.2−.2)	(-1.7−.4)
	QO.	86/11/2	80/15/4	85/12/3	25/18/57	4/77/19	10/75/16	7/9/83	5/67/27	5/8/87	9/14/77
HIA/min	% Diff	52±40	-4±39	-.6±47.1	-32.1±91.1	-35.3±21.4	-32±15.7	-40.6±58.7	1.8±15.4	-7.9±58.2	-17.6±46.4
	ES and	.8	-.1	-.0	-.8	-.7	-.6	-.8	.0	-.1	-.4
	90%CI	(.2−1.5)	(-.7−.6)	(-.8−.8)	(-2.1−.5)	(-1.0 −-.4)	(-.9−-.4)	(-1.6 −-.1)	(-.2−.3)	(-.9−.6)	(-1.2−.4)
	QO.	94/5/1	23/40/37	31/35/33	10/12/78	0/1/99	0/0/100	1/6/92	11/83/6	22/33/44	10/22/67
HIHR/min	% Diff	-46±174	-23±313	-23±243	224±460	-37±52	.4±83	-13±154	28±94	178±357	76±164
	ES and	-.5	-.2	-.2	1.0	-.3	.0	-.1	.2	1.0	.5
	90% CI	(-1.4−.3)	(-1.4−1.0)	(-1.3−.8)	(-.5−2.4)	(-.6−-.0)	(-.4−.4)	(-1.9−1.8)	(-.4−.8)	(-.5−2.4)	(-.3−1.3)
	QO.	7/17/76	26/24/51	22/27/52	84/8/8	1/24/75	19/63/18	37/18/45	54/36/11	85/7/8	74/18/8

%Diff- percentage difference; CI: confidence interval; ES: effect size; HIA/min: high-intensity activity per minute; HIHR/min: high-intensity heart rate per minute; LIA/min: low-intensity activity per minute; m/min: meterage per minute; M1: match 1; M2: match 2; M3: match 3; M4: match 4; M5: match 5; PL/min: player load per minute; QO.: qualitative outcome

The relative (80 m/min) distances measured in the current study are lower than those reported for elite female players (Andersson et al., 2010; Bradley et al., 2014; Mohr et al., 2008; Ramos et al., 2017; Vescovi, 2014; Vescovi and Favero, 2014), Currently, no methodological standardisation of velocity thresholds to accurately quantify locomotor activities during female soccer matches exists, limiting comparisons between studies to develop cohesive views concerning locomotor characteristics of female soccer (Bradley and Vescovi, 2015). In line with previously described velocity zones used for female players (Vescovi, 2014; Vescovi and Favero, 2014), the distances covered by the players from the current study in each velocity zone differed, with players spending 42% standing/walking, 11% jogging, 23% LIR, 11% MIR, 5% HIR and 1% sprinting. Specifically in the HIR and sprinting zones, performance was lower than previous findings (7.5% HIR and 2.5% sprinting) for sub-elite players (Vescovi and Favero, 2014). These findings can be influenced by elements such as physical fitness of the players, game strategies of the players, opposition team standard and formations (Hewitt et al., 2014; Mohr et al., 2008, Mara et al., 2017; Marqués-Jiménez et al., 2017).

Similar to previous studies using GPS or video analysis (Mohr et al., 2008; Ramos et al., 2017; Vescovi, 2014; Vescovi and Favero, 2014), positional distinctions were evident, with midfielders recording the furthest absolute total distance. Consequently, midfielders achieved the highest relative total distance, which was significantly greater than the results noted for defenders, which is in agreement with a previous study (Vescovi and Favero, 2014). These finding can be attributed to the positional demands of midfielders fulfilling a linking role between the front and back players, justifying the higher work rate (Di Salvo et al., 2007). Results further concur with previous findings on sub-elite female players whereby forwards covered the greatest distance at HIA (consisting of HIR and sprinting) (Vescovi and Favero, 2014). These findings could be of importance to coaches and conditioning specialists in planning training programmes to enhance position-specific performance to compete on a higher standard.

The use of player load in addition to GPS-based speed data may provide a more accurate indication of the demands imposed by soccer-specific non-running activities (Scott et al., 2013). A study on female soccer players examining player load using a similar method could not be found, and therefore comparisons are limited and results of the current study are discussed in line with tendencies found among male soccer players concerning playing position. A significant ($p \leq 0.05$) difference was found between the player load of midfielders compared to forwards and defenders, while forwards and defenders had comparable values. Once again the higher player load recorded for the midfielders can be justified by the linking role these players fulfil during a match (Di Salvo et al., 2007). It can in addition be posed that the higher level of manoeuvrability required by midfielders to perform their positional tasks could have a higher player load as a result due to performing more movement activities. With the purpose of designing training programmes specific to the different playing positions, an understanding of the different ways in which players from these different positions achieve load is necessary (Dalen et al., 2016). Differences in playing formations, playing standards, effective playing time and score line are all factors that would affect positional activity profiles and should be considered when making comparisons (Barron et al., 2014).

It is believed that, in team-sport match analysis, the players' inability to maintain the running performance within the first half of a match to the second half suggests player fatigue (Furlan et al., 2015). Total distance within matches decreased significantly ($p \leq 0.05$) with 11% from the first to the second half. Studies on elite level female players also noted significant ($p \leq 0.05$) differences between the first and second half (Andersson et al., 2010; Mohr et al., 2008). Furthermore there were decreases in relative distance (8%; ES: possibly small), LIA (7%; ES: likely small, HIA (6%; ES: possibly trivial) and Player load (ES: likely small) between first and second half. These results suggest that the players either exert more efforts/intense movements during the first half, which can be explained by a particular strategy used in order to physically challenge the opposing team more during the first half. Alternatively, these results could be evidence of fatigue experienced in the first half leading to lower performance in the second half. The reduction of HIR towards the end of a match could be a result of fatigue, but can also be influenced by other factors such as game tactics (Mohr et al., 2008, Andersson et al., 2010). Improving female players' ability to perform HIA towards the end of a match (through high-intensity aerobic and speed-endurance training) should be emphasised in training programmes, consequently equipping players with the possibility of out-playing the opponent and creating more scoring opportunities.

The tournament structure and number of matches played within the week should, however, also be considered when interpreting these results. The influence of multiple matches on exercise intensity and the effect of fatigue during a tournament has been investigated in other field team sports (Jennings et al., 2012; Inglis and Bird, 2017). Increased match intensity and frequency highlight the importance of proper recovery interventions between matches in order to continually perform at an optimal level (Andersson et al., 2008). It appears that when Match 1 was compared to Match 2, 3 and 4, the positive changes observed in relative distance, LIA and PL are an indication of likely small to moderate higher performance, with the lowest performance produced in Match 1. The lower performance produced in Match 1 can possibly be attributed to a pacing strategy employed in an attempt to conserve energy for the coming matches. It is also reasonable to expect that during the first match the players experienced a higher level of anxiety as it is the start of a tournament, which could have resulted in players not performing to the best of their abilities. Match analyses from the second to the final matches generally showed gradual but small to moderate reductions in variables measured. These results are in accordance with differences observed in running intensities throughout field hockey and rugby tournaments (Higham et al., 2012; Inglis and Bird, 2017; Jennings et al., 2012). Relative distance and LIA saw the greatest noteworthy likely negative difference when Match 5 was compared with Match 2 and Match 3, with a moderate to large effect size. High-intensity activity also likely decreased with a small effect from Match 2 to Match 4, and with a moderate effect from Match 2 to Match 5. In addition, player load saw the largest likely decrease between Match 2 and Match 5 and indicated unclear results when Match 3 and Match 4 were compared with Match 5. The preservation of performance between Matches 2, 3 and 4 suggests that transient fatigue is accumulated during a match and that accumulated fatigue has a minimal effect on performance during Match 3 and 4. It is also possible that a specific pacing strategy was used or sufficient recovery methods employed to minimise fatigue build-up in a tournament of this particular structure, or that a combination of these tactics assisted in relative maintenance of performance. The importance of Match 4, which was the semi-finals, could also have played a role in the maintenance of performance in this match. Since Match 4 was a qualifier to progress to the finals, it is typical to expect that players would maximise their efforts in a last attempt to progress to the final match of the tournament. Although, the reduced performance measured across all variable in the final match should provide sufficient evidence of the effect of residual fatigue from the previous match and accumulated fatigue throughout the tournament, resulting in decreased intensities at the end of a tournament. A study on female soccer players found that mean HR and HIR performance were not impaired where two matches were interspersed by two days. In the current study, the load of the competition may have impaired the players' performance due to insufficient recovery between matches, consequently leading to shorter distances covered in total and within each velocity zone, specifically at HIA. Another notion to consider is the strength of the opposition team. Player density and space available for running may be reduced in matches against higher- or lower ranked teams (Hewitt et al., 2014). A team dominating ball possession can lead to a greater number of players in one half of the field, thereby decreasing running space, while playing against opposition of relatively similar strength increases opportunities to move from the defensive to the offensive half (Hewitt et al., 2014). Match analysis of all teams within such a tournament are recommended for future analyses in order to compare teams of different ranking and make conclusive recommendations.

The clarification of internal match demands in addition to external demands could provide a more detailed description of the physical demands placed on soccer players. Vital information provided by HR monitoring can assist to prevent overtraining or understimulation of the cardiovascular system (Ohlsson et al., 2015). The average HR reported in the current study was lower than previous reported values for elite female players (Andersson et al., 2010; Krustrup et al., 2010; Ohlsson et al., 2015). When expressed according to the percentage of time spent in different HR zones based on HR_{max}, the results of the players in the current study differed from a previous report on elite female players (Ohlsson et al., 2015). The players in the current study spent most of the time in zones 60–75 and 75–85% of HR_{max}, whereas elite players spent the least amount of time in these two zones (5 and 18%, respectively) (Ohlsson et al., 2015). Elite players also spent the highest amount of time (32%) in the 90–95% of HR_{max} zone in contrast to the 10% achieved by the players of the current study, and spent a combined total time of 55% at HIHR (>90% of HR_{max}) (Ohlsson et al., 2015). It is evident that performance at HIHR may be a factor distinguishing female players of different standards. The reduced time spent in the HIHR zones in the second half suggests a decrease in the physical work performed and the occurrence of physical fatigue (Rampinini et al., 2008). A possibility exists that the magnitude of change observed in HIR/min is related to the results noted for HIHR/min and recommends further research, as both these measures produced only possible trivial reductions. Unlike with the external match demand variables discussed, changes ranged between trivial and small for HIHR, but did not follow a specific trend regarding increases or decreases observed. Even though it appears in this study that HIHR may not be a factor to consider in isolation when discussing match demands throughout a tournament, more research is required to justify the current findings.

In conclusion, the amount of HIA is lowered towards the second half of a match, suggesting the possibility of fatigue influencing HIA movements. Altogether, these findings indicate that sub-elite female players experience fatigue during a match and throughout a tournament consisting of matches played on consecutive days. There are however a few limitations to be considered. Factors such as differences in match analyses, match periods, playing formations and opposition team status and strategies should be considered when interpreting the results, although these factors cannot be controlled in field-based research. Positional specificity is also apparent. Sport scientists and researchers are encouraged to use specific velocity zones associated with female players and to consider the variables identified in order to create consistency and elaborate on the limited data available, thereby expanding the possibility for comparing and justifying results and compiling position-specific training programmes. The tactical use of player substitutions by coaches in the latter periods of a match could be a strategy in an attempt to lessen the effect of fatigue on the players' and teams' performance. Although the movement profile of substitute players was beyond the scope of this paper and warrants future studies. The present findings give a unique description of the match demands of sub-elite female soccer players. It identifies specific changes in match variables throughout a tournament, which can be attributed to accumulated fatigue, filling a critical knowledge gap not only in South Africa, but also adding to what is currently known about players on this level worldwide.

Practical applications

An important factor to consider is the structure of the tournament during which data collection occurred. Physical attributes of players may be compromised by insufficient recovery between matches, leading to the build-up of fatigue and decreased performance, particularly towards the end of a tournament.

Conclusion

In summary, this research elaborates on the limited literature on the match demands of sub-elite female soccer players and can assist coaches and strength and conditioning specialists to compile training programmes to appropriately develop female soccer players on sub-elite level and improve performance on the field. Small reductions in the work rate of players can be expected between the first and second half of a soccer match and the use of tactical player substitutions can assist to maintain the work rate of the team. Reports analysing movement patterns per minute of play is necessary to account for these differences in match time variability. A potential limitation of this study was that not all players competed in all the matches, which could have had an influence on the determination of fatigue throughout the tournament. Furthermore, due to only two teams being assessed throughout the tournament, conclusions on team ranking within the particular tournament could not be made and should be considered in future research.

Acknowledgements

The authors wish to acknowledge all the members of the research team who took part in the data collection procedure. The authors wish to express their gratitude towards the players, coaches and team managers for their dedication and enthusiastic participation in the study. This work is based on the research supported in part by the Tshwane University of Technology (TUT) South Africa, through the Department of Higher Education and Training Research Development Grant. The authors declare that they have no competing interests. The study was approved by the Health Research Ethics Committee of the North-West University, South Africa (NWU-00055-15-A1). The experiments comply with the current laws of the country in which they were performed. The authors have no conflicts of interests to declare.

References

Andersson, H. A., Randers, M. B., Heiner-Moller, A., Krustrup, P. and Mohr, M. (2010) Elite female soccer players perform more high-intensity running when playing in international games compared with domestic league games. *The Journal of Strength & Conditioning Research* **24,** 912-919.

Andersson, H. M., Raastad, T., Nilsson, J., Paulsen, G., Garthe, I. and Kadi, F. (2008) Neuromuscular fatigue and recovery in elite female soccer: effects of active recovery. *Medicine & Science in Sports & Exercise* **40,** 372-380.

Bangsbo, J. (1993) The physiology of soccer--with special reference to intense intermittent exercise. *Acta Physiologica Scandinavica* **Supplementum 619,** 1-155.

Barbero Álvarez, J. C., Gómez López, M., Barbero Álvarez, V., Granda Vera, J. and Castagna, C. (2008) Heart rate and activity profile for young female soccer players. *Journal of Human Sport and Exercise* **3(2),** 1-11.

Barron, D. J., Atkins, S., Edmundson, C. and Fewtrell, D. (2014) Accelerometer derived load according to playing position in competitive youth soccer. *International Journal of Performance Analysis in Sport* **14,** 734-743.

Batterham, A. M. and Hopkins, W. G. (2006) Making meaningful inferences about magnitudes. *International Journal of Sports Physiology and Performance* **1,** 50-57.

Bendiksen, M., Pettersen, S. A., Ingebrigtsen, J., Randers, M. B., Brito, J., Mohr, M., Bangsbo, J. and Krustrup, P. (2013) Application of the Copenhagen Soccer Test in high-level women players - locomotor activities, physiological response and sprint performance. *Human Movement Science* **32,** 1430-1442.

Bradley, P. S., Dellal, A., Mohr, M., Castellano, J. and Wilkie, A. (2014) Gender differences in match performance characteristics of soccer players competing in the UEFA Champions League. *Human Movement Science* **33,** 159-171.

Bradley, P. S., Sheldon, W., Wooster, B., Olsen, P., Boanas, P. and Krustrup, P. (2009). High-intensity running in English FA Premier League soccer matches. *Journal of Sports Sciences* **27,** 159-168.

Bradley, P. S. and Vescovi, J. D. (2015) Velocity thresholds for women's soccer matches: sex specificity dictates high-speed running and sprinting thresholds - Female Athletes in Motion (FAiM). *International Journal of Sports Physiology and Performance* **10,** 112-116.

Carling, C., Bloomfield, J., Nelsen, L. and Reilly, T. (2008) The role of motion analysis in elite soccer: contemporary performance measurement techniques and work rate data. *Sports Medicine* **38,** 839-862.

Castagna, C., Impellizzeri, F. M., Chaouachi, A., Bordon, C. and Manzi, V. (2011) Effect of training intensity distribution on aerobic fitness variables in elite soccer players: a case study. *The Journal of Strength & Conditioning Research* **25,** 66-71.

Cunniffe, B., Proctor, W., Baker, J. S. and Davies, B. (2009) An evaluation of the physiological demands of elite rugby union using global positioning system tracking software. *The Journal of Strength & Conditioning Research* **23,** 1195-1203.

Dalen, T., Jorgen, I., Gertjan, E., Geir Havard, H. and Ulrik, W. (2016). Player Load, Acceleration, and Deceleration During Forty-Five Competitive Matches of Elite Soccer. *The Journal of Strength & Conditioning Research* **30,** 351-359.

Datson, N., Hulton, A., Andersson, H., Lewis, T., Weston, M., Drust, B. and Gregson, W. (2014) Applied physiology of female soccer: an update. *Sports Medicine* **44,** 1225-1240.

Di Salvo, V., Baron, R., Tschan, H., Calderon Montero, F., Bachl, N. and Pigozzi, F. (2007) Performance characteristics according to playing position in elite soccer. *International Journal of Sports Medicine* **28,** 222-227.

Edwards, A. M. and Noakes, T. D. (2009) Dehydration: cause of fatigue or sign of pacing in elite soccer? *Sports Medicine* **39,** 1-13.

Furlan, N., Waldron, M., Shorter, K., Gabbett, T. J., Mitchell, J., Fitzgerald, E., Osborne, M. A. and Gray, A. J. (2015) Running-intensity fluctuations in elite rugby sevens performance. *International Journal of Sports Physiology and Performance,* **10,** 802-807.

Gabbett, T. J. and Mulvey, M. J. (2008) Time-motion analysis of small-sided training games and competition in elite women soccer players. *The Journal of Strength & Conditioning Research* **22,** 543-552.

Gaudino, P., Iaia, F. M., Strudwick, A. J., Hawkins, R. D., Alberti, G., Atkinson, G. and Gregson, W. (2015) Factors Influencing Perception of Effort (Session Rating of Perceived Exertion) During Elite Soccer Training. *International Journal of Sports Physiology and Performance* **10(7),** 860-864.

Hewitt, A., Norton, K. and Lyons, K. (2014) Movement profiles of elite women soccer players during international matches and the effect of opposition's team ranking. *Journal of Sports Sciences* **32,** 1874-1880.

Higham, D. G., Pyne, D. B., Anson, J. M. and Eddy, A. (2012) Movement patterns in rugby sevens: effects of tournament level, fatigue and substitute players. *Journal of Science and Medicine in Sport* **15,** 277-282.

Hopkins, W. (2003) A spreadsheet for analysis of straightforward controlled trials. *Sportscience* **7**. *Available from sportsci. org/jour/03/wghtrials. htm.[Accessed 10 January 2012.]*.

Inglis, P. and Bird, S. P. (2017) Movement Demands and Running Intensities of Semi-Professional Rugby League Players during A 9's Tournament: A Case Study. *Journal of Sports Science and Medicine* **16,** 22-26.

Jennings, D., Cormack, S. J., Coutts, A. J. and Aughey, R. J. (2012) GPS analysis of an international field hockey tournament. *International Journal of Sports Physiology and Performance* **7,** 224-231.

Krustrup, P., Mohr, M., Ellingsgaard, H. and Bangsbo, J. (2005) Physical demands during an elite female soccer game: importance of training status. *Medicine and Science in Sports and Exercise* **37,** 1242-1248.

Krustrup, P., Zebis, M., Jensen, J. M. and Mohr, M. (2010) Game-induced fatigue patterns in elite female soccer. *The Journal of Strength & Conditioning Research* **24,** 437-441.

Mara, J. K., Thompson, K. G., Pumpa, K. L. and Morgan, S. (2017) Quantifying the High-Speed Running and Sprinting Profiles of Elite Female Soccer Players During Competitive Matches Using an Optical Player Tracking System. *The Journal of Strength & Conditioning Research* **31,** 1500-1508.

Marqués-Jiménez, D., Calleja-González, J., Arratibel, I., Delextrat, A. & Terrados, N. (2017) Fatigue and recovery in soccer: evidence and challenges. *The Open Sports Sciences Journal,* **10.**

Martínez-Lagunas, V., Niessen, M. and Hartmann, U. (2014) Women's football: Player characteristics and demands of the game. *Journal of Sport and Health Science* **3,** 258-272.

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

Ohlsson, A., Berg, L., Ljungberg, H., Söderman, K. and Stålnacke, B.-M. (2015) Heart Rate Distribution during Training and a Domestic League Game in Swedish Elite Female Soccer Players. *Annals of Sports Medicine and Research* **2,** 1025.

Ramos, G. P., Nakamura, F. Y., Penna, E. M. and Coimbra, C. (2017) Activity profiles in U17, U20 and senior women's Brazilian National soccer teams during international competitions: Are there meaningful differences? *The Journal of Strength & Conditioning Research*. Epub ahead of print. July 31.

Rampinini, E., Impellizzeri, F. M., Castagna, C., Azzalin, A., Ferrari Bravo, D. and Wisloff, U. (2008) Effect of match-related fatigue on short-passing ability in young soccer players. *Medicine & Science in Sports and Exercise* **40,** 934-942.

Scott, B. R., Lockie, R. G., Knight, T. J., Clark, A. C. and Janse De Jonge, X. (2013) A comparison of methods to quantify the in-season training load of professional soccer players. *International Journal of Sports Physiology and Performance* **8,** 195-202.

Trewin, J., Meylan, C., Varley, M. C. and Cronin, J. (2018) The match-to-match variation of match-running in elite female soccer. *Journal of Science and Medicine in Sport* **21,** 196-201.

Varley, M. C., Fairweather, I. H. and Aughey, R. J. (2012) Validity and reliability of GPS for measuring instantaneous velocity during acceleration, deceleration, and constant motion. *Journal of Sports Sciences* **30,** 121-127.

Varley, M. C., Gabbett, T. and Aughey, R. J. (2014) Activity profiles of professional soccer, rugby league and Australian football match play. *Journal of Sports Sciences* **32,** 1858-1866.

Vescovi, J. D. (2014) Motion characteristics of youth women soccer matches: Female Athletes in Motion (FAiM) Study. *International Journal of Sports Medicine* **35,** 110-117.

Vescovi, J. D. and 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,** 405-414.

Key points

- This is the first study of its kind conducted on female soccer players in South Africa, and the African continent.
- Forwards covered the greatest distance at high-intensity during matches.
- The largest magnitude of change was seen with a large decrease (ES: -1.2) in relative distance covered between match 2 and 5.
- Accumulated fatigue build up throughout a tournament will influence performance negatively.

AUTHOR BIOGRAPHY

Anita STRAUSS
Employment
Tshwane University of Technology; Department of Sport, Rehabilitation & Dental Science; Pretoria; South Africa; 0001.
Degree
PhD
Research interest
Sport science; Sport-specific skills; Soccer match analysis
E-mail: straussa@tut.ac.za

Martinique SPARKS
Employment
North-West University; Physical Activity, Sport and Recreation (PhASRec); Potchefstroom; South Africa; Private Bag X6001.
Degree
PhD
Research interest
Sport Science; Sport analysis
E-mail: Martinique.sparks@nwu.ac.za

Cindy PIENAAR
Employment
North-West University; Physical Activity, Sport and Recreation (PhASRec); Potchefstroom; South Africa; Private Bag X6001.
Degree
PhD
Research interest
Sport Science; Sport and exercise physiology
E-mail: cindyp@dut.ac.za

✉ **Anita Strauss**
Department of Sport, Rehabilitation & Dental Science; Faculty of Science, Tshwane University of Technology, Pretoria West Campus; Pretoria; 0001; South Africa