This is a pre-copyedited, author-produced version of an article accepted for publication in Journal of Strength and Conditioning Research. The published version of record Match Exposure, Consecutive Match Number, and Recovery Days Affect Match Running During International Women's Soccer Tournaments http://doi.org/10.1519/JSC.0000000000004667

Title: Match exposure, consecutive match number and recovery days affect match running during international female soccer tournaments.

Abstract

To determine the influence of tournament-specific factors (match exposure, consecutive matches, days between matches) on match running in female international soccer players (footballers), 28 players from one women's national team were observed over 4 international tournaments using 10Hz global positioning system units. Linear mixed-models with a forward selection approach were used to analyze the collective effect of tournament-specific factors of match exposure (playing time), consecutive matches (count), days between matches (count) and time on pitch on relative (/min) match running metrics (total distance, high-speed running, very high-speed running, accelerations, decelerations) and the change in these metrics between halves. Significance level was set at $p<0.05$. Days between matches was included in the final models for total distance ($p<0.0001$), high-speed running ($p=0.002$), very high-speed running ($p=0.025$) and change in accelerations ($p<0.0001$) and decelerations ($p=0.002$). Prior match exposure was included in the models for total distance ($p=0.021$), change in total distance ($p<0.0001$) and change in high-speed running ($p=0.0008$). Consecutive match number was included in the model for deceleration ($p=0.030$), change in very high-speed running ($p=0.016$), change in acceleration ($p<0.0001$) and change in deceleration ($p<0.0001$). Time on pitch was included in the final total distance ($p=0.044$), high-speed running ($p<0.0001$), acceleration ($p<0.0001$) and deceleration ($p=0.0003$) models. Overall, reduced match running throughout tournaments was associated with increased time on pitch and $\leq$3 days between matches. Increasing match exposure and more time between matches minimizes reductions in match running between halves. Practitioners can use these variables to inform player monitoring during international soccer tournaments and on return to clubs.

Key words: GPS, football, match analysis, women, congested schedules

INTRODUCTION

International soccer (football) tournaments are prestigious competitions, that often require teams to play multiple consecutive matches, resulting in congested scheduling, reduced recovery time and accumulating match exposure for players (21, 25). Within matches, female soccer players cover approximately 10km total distance each match, with many high-speed actions, accelerations and decelerations (12, 16) of which high-speed running has been associated with tournament placing (24) and goal scoring opportunities (7). Often international tournaments schedule matches every 3 days for multiple games or entire tournaments (e.g., 2020 Olympics, 2020 Olympic qualifiers, 2022 AFC Asian Cup), whilst the majority of women's domestic league competitions schedule one game per week with infrequent midweek games for continental club competitions. The demanding schedules of international tournaments potentially affects match running outcomes; as physiological (creatine kinase, interleukin-6), neuromuscular (speed, power) and perceptual (muscle soreness) responses require 3 to 5 days to return to pre-match values (1, 10, 26). However, whilst the match running demands of female soccer players have been reported, these are usually collective descriptions of singular games, rather than tournament focused (2, 5, 27). Accordingly, limited evidence exists on the influence of repeated match exposure within international women's tournaments on match running demands between and within matches. Understanding how match running may be affected by factors specific to international tournaments (e.g., congested scheduling, recovery days) can inform player preparation, recovery practices and team selection during women's international tournaments (25).

Whilst match running is affected by a multitude of contextual factors (27), no exploration of the combined influence of congested scheduling (short recovery time between matches), prior match exposure (minutes played in a tournament) and consecutive match number on

52 women's soccer match running demands exists. Evidence on the influence of congested
53 scheduling (days between matches) on international women's soccer match running is
54 limited, with only one study reporting no effect of recovery time (<72h vs >72h) in female
55 international soccer players (27), concurring with findings in men's international tournaments
56 (25). This is despite some recovery markers remaining below baseline 72h following a soccer
57 match (9). Whether increased match exposure or playing consecutive matches in a
58 tournament has an effect is unknown; having not been explored in isolation or in combination
59 with scheduling factors, though increased injury risk with increased match exposure has been
60 observed (19). Hence, greater insight to the collective effects of days between matches, prior
61 match exposure and consecutive matches played during a tournament on female players
62 match running can assist coaches and performance staff in player preparation and recovery.
63
64 Match running demands can also change between halves within matches, as evidenced by
65 total, high-speed running (19.8-25.1km·h^{-1}) and sprint distances (>25.1km·h^{-1}) decreasing in
66 the second half of women's international soccer matches, regardless of playing position (5).
67 Within-match running demands are influenced by a range of external factors, such as tactics
68 and opponent quality (23), whilst previous research also attributed relative match running
69 reductions to fatigue due to the decrements in sprint ability and intermittent exercise
70 performance immediately following competitive women's matches (17). One study found a
71 greater reduction in between-half total high-speed running in matches 5 (quarter final) and 7
72 (third place play-off) compared to all other matches for a 2019 Women's World Cup team
73 (29). The authors speculated that repeated match exposure with a short rest period (i.e., less
74 days between matches) and higher demands from extra time (i.e., increasing match exposure)
75 contributed to the reduction – however these factors remain to be analyzed, despite the
76 importance for international tournaments. Thus, understanding how the specific challenges of

77 tournaments (prior match exposure, match number and days between matches) influence the
78 between-half change in match running demands is important for training prescription,
79 recovery and substitutions/squad rotations.
80
81 Given the lack of research on women's international soccer tournaments, the aims of this
82 study were to determine the combined influence of tournament specific factors (prior match
83 exposure, days between matches, consecutive matches played) on 1) whole-match running
84 performance and 2) change in match running performance between halves.
85
86 **METHODS**
87 **Experimental approach to the problem**
88 To understand the effects of tournament exposure, schedules and recovery days on match
89 running, data was collected from 28 professional female soccer players across four major
90 international tournaments between 2019 and 2021. Physical match data was recorded using
91 10 Hz global positioning system units (GPS; STATSports, Apex, Northern Ireland). Five
92 GPS metrics (total distance, high-speed running distance, very high-speed running distance,
93 acceleration count, deceleration count) were converted to relative metrics (/min) for whole of
94 match and within match (change between halves) analysis. Tournament specific factors (days
95 between matches, prior match exposure and consecutive match number) were collated and
96 their collective effects on the GPS metrics were determined using linear mixed models.
97
98 **Subjects**
99 Data was collected from twenty-eight female soccer players (age 26.3 ± 4.1 years, range 18-
100 36 years; weight 61.8 ± 4.9kg) from one national soccer team (player characteristics included
101 in Table 1). All players (excluding goalkeepers) who played >10 min in a match at specified

tournaments were included. Given match running differences exist between positions (11) playing position was categorized using five positional groups based on the team formation reported by the National Federation (central defender, wide defender, central midfielder, wide midfielder, forward). All data collection involved standardized procedures for national team players, and consent to use data was provided by the National Federation. Ethical approval was also provided by the Institutional Ethics Committee (ETH22-7023).

INSERT TABLE 1 ABOUT HERE

Procedures

Physical match load

External load was measured using 10 Hz GPS units (STATSports, Apex, Northern Ireland). The device has been validated and deemed reliable for a range of distance and speed-based variables in team sports with a <3% bias (4). Devices were turned on outside prior to data collection to allow time for satellite connection. All players wore GPS vests to hold the GPS devices securely between their scapulae. Players wore the same GPS device within a tournament to minimize inter-unit measurement error.

Following each match, data was downloaded and processed using the manufacturer software (STATSports Sonra, Apex, Northern Ireland). Total distance, high-speed running distance (>18-25km·h^{-1}), very high-speed running distance (>25km·h^{-1}) and acceleration and decelerations counts (>2m·s^{2}) were used as match running metrics (based on previous women's soccer research) (2, 15). Data for players who played greater than 10 min in a match were included in the *whole-match* analyses and players who played greater than 10 min in both halves of a match were included in the analyses for *change between halves*. Each measure was converted to relative metrics (m·min^{-1} or count·min^{-1}) to account for individual

differences in time on pitch. Change between halves was calculated as (relative GPS variable in second half) – (relative GPS variable in first half).

Tournament specific factors

Tournament specific factors included 1) days between matches, 2) prior match exposure and 3) consecutive match number. The number of days between matches (1) was categorized as ≤ 3 days (≤ 72h), 4-7 days and ≥ 8 days, calculated from the end of one match to the start of the next. Prior match exposure (2) was calculated by summing the total match minutes played by an individual in a tournament prior to the match of interest. Consecutive match number (3) was defined as the consecutive match played within a tournament for an individual. Due to the inclusion of players with >10 min, time on pitch was also measured. Time on pitch (min) was determined from GPS output, summing a player's total minutes within a match (first half, second half, extra time). The half-to-half time on pitch difference (min) was calculated by (second half duration – first half duration).

Statistical Analyses

Linear mixed-models using 'lme4' package (3) were used to determine which independent variables (time on pitch and tournament specific factors; 1) days between matches, 2) prior match exposure and 3) consecutive match number) affected the outcome variables (relative GPS metrics for whole-match and change between halves; total distance, high-speed running distance, very high-speed running distance, acceleration count, deceleration count). A forward selection approach to building each model was used whereby one fixed effect was introduced at a time and assessed by examining the model's Akaike information criterion, R^2 values and significance to determine the "best" models. Player ID, positional group and tournament were included as random effects in all models, whilst days between matches,

prior match exposure and match number were specified as fixed effects. Time on pitch was included in the whole-match models, and half-to-half time on pitch difference was included in the change between halves models as fixed effects. In several models, player ID and positional group provided 0 variance creating a singular fit issue. Players with only 1 match were removed from the database and the models were re-run. This was repeated for players with 2 and 3 matches. Model fits were not improved, and subsequently [positional group] was removed as a random effect in the affected models (whole-match acceleration, whole-match deceleration, all change between halves models) but [player ID] was retained in the affected models (change in total distance, accelerations and decelerations between halves) to account for repeated measures and non-independence. Following variable selection of each model, post-hoc pairwise comparisons for categorical variables were made within variables (i.e., holding other variables constant) using estimated marginal means calculated by 'emmeans' package (18) and Tukey's adjustment. Significance level was set at $p < 0.05$. All analyses were completed using R statistical software (version 4.0.0).

RESULTS

The variables included in the final model for each GPS metric as selected by the forward selection process are shown in Table 2.

INSERT TABLE 2 ABOUT HERE

Whole-match relative GPS metrics

Figure 1 shows the relationship between whole-match GPS distance-based metrics (total, high-speed, very high-speed distance) and the independent variables selected from the forward selection linear mixed-model. Days between matches, prior match exposure and time

177 on pitch were included in the final total distance model. Whilst keeping prior match exposure
178 and time on pitch constant, relative total distance ($m \cdot min^{-1}$) is significantly lower when there
179 are ≤3 compared to 4-7 days ($p < 0.0001$) and ≥8 days between matches ($p=0.0028$; Figure
180 1a). Additionally, with each 1-min increase in prior match exposure and time on pitch, total
181 distance reduces by $0.01 m \cdot min^{-1}$ and $0.03 m \cdot min^{-1}$ respectively. Time on pitch and days
182 between matches were included in the final high-speed running distance model. Relative
183 high-speed running distance ($m \cdot min^{-1}$) is significantly lower for ≤3 days compared to 4-7
184 days ($p=0.0074$) and ≥8 days between matches ($p=0.0178$), where time on pitch is kept
185 constant (Figure 1b). Additionally, with each 1-min increase in time on pitch, high-speed
186 running reduces by $0.02 m \cdot min^{-1}$. Although days between matches was a significantly
187 influential factor for very high-speed running distance, pairwise comparisons revealed no
188 significant differences between days between matches ($0.17 m \cdot min^{-1}$ increase when 4-7 days
189 vs ≤3 days, $0.23 m \cdot min^{-1}$ increase when ≥8 days vs ≤3 days; $p>0.05$; Figure 1c).
190
191 *INSERT FIGURE 1 ABOUT HERE*
192
193 Figure 2 shows the relationship between whole-match count-based metrics (acceleration,
194 deceleration) and the independent variables determined from the forward selection linear
195 mixed-model. Time on pitch was the only fixed effect in the relative acceleration count
196 model ($p<0.0001$; Figure 2a). With each 1-min increase in time on pitch, acceleration count
197 reduces by $0.003 count \cdot min^{-1}$. Time on pitch and consecutive match number were included in
198 the final deceleration count model. Where time on pitch is kept constant, there is a significant
199 difference in relative deceleration count only between match 1 and match 2 ($0.14 count \cdot min^{-1}$
200 difference; $p = 0.0174$; Figure 2b). Additionally, with each 1-min increase in time on pitch,
201 deceleration count reduces by $0.003 count \cdot min^{-1}$.

INSERT FIGURE 2 ABOUT HERE

Change between halves relative GPS metrics

Figure 3 shows the relationship between change in distance-based GPS metrics between halves (total distance, high-speed distance, very high-speed running distance) and the independent variables from the forward selection linear mixed-model. Half-to-half time on pitch difference and prior match exposure were included in the final model for change in total distance (Figure 3a). With each 1-min increase in half-to-half time on pitch difference and prior match exposure, change in total distance increases by $0.32 m \cdot min^{-1}$ and $0.02 m \cdot min^{-1}$ respectively. Prior match exposure was the only fixed effect in the final change in high-speed running distance ($p=0.0008$; Figure 3b) model, where each 1-min increase in prior match exposure improves change in high-speed running by $0.005 m \cdot min^{-1}$. Consecutive match number was the only fixed effect in the change in very high-speed running distance model. Significant differences were only found between matches 1 and 2, where there is an increase in relative very high-speed running distance in the second half of match 2 but a decrease in match 1 ($0.3 m \cdot min^{-1}$ difference between match 1 and 2; $p = 0.0339$; Figure 3c).

INSERT FIGURE 3 ABOUT HERE

Figure 4 demonstrates the relationship between change in count-based acceleration and deceleration metrics between halves and the independent variables selected from the forward selection linear mixed-model. Days between matches and consecutive match number were included in the final models for change in acceleration count and change in deceleration count. The difference in relative acceleration count between halves is lower when there are

≥8 days between matches compared to ≤3 days ($p=0.0151$) or 4-7 days ($p<0.0001$; Figure 4a). Additionally, there are significantly greater reductions in relative acceleration count between halves in match 1 compared to all other consecutive matches (0.69-0.88count·min^{-1} difference; $p<0.0001$). In terms of change in relative deceleration count, there is a lower difference between halves when there are ≥8 days between matches compared to 4-7 days (0.172count·min^{-1} difference; $p=0.0378$; Figure 4b). Further, there is a significantly greater reduction in relative deceleration count between halves in consecutive match 2 compared to matches 3 and 4 (1.28count·min^{-1} and 1.56count·min^{-1} difference respectively; ($p<0.0001$), and in match 5 compared to match 4 (1.34count·min^{-1} difference; $p=0.0228$).

INSERT FIGURE 4 ABOUT HERE

DISCUSSION

This is the first study to use a multivariate approach to assess the influence of a combination of tournament specific scheduling factors on match running in international female soccer players. Time on pitch was the strongest and most frequently selected variable for *whole-match* GPS models. Days between matches, prior match exposure and consecutive match number also had significant relationships with match running outcomes. Consecutive match number was the most influential variable for the *change between halves* models, followed by prior match exposure and days between matches. Regardless of tournament or player factors, fewer recovery days and greater match playing exposure were associated with reduced match running as a tournament progresses in female soccer players. However, variable effects exist for days between matches, prior match exposure and consecutive match number on the between-half change in match running. These novel findings should be considered within the context of each match (match outcome, opponent quality, environment (27)) and player (tactics, position). Hence, careful consideration of appropriate recovery, training exposure

and squad selection may be required by coaches when aiming to optimize the ability to undertake match running demands during international tournaments.

International female soccer players' match running may be reduced when exposed to longer time on pitch, increased match exposure and fewer days between matches. Longer time on pitch reduces total distance, high-speed running, accelerations and decelerations, and may relate to self-employed pacing strategies (28) or acute match fatigue (17). Previous research outlines both physiological (reduced muscle glycogen and muscle phosphocreatine) and perceptual (increased reported fatigue) responses that affect physical performance during and after soccer matches, that may align with the current observations in women's soccer (16). Regardless of time on pitch, matches played within 3 days, representing congested schedules, was associated with reduced total and high-speed running distance. These findings contrast with Trewin et al. (27) who reported no effect of <72h compared to >72h between matches on match running variables ($m \cdot min^{-1}$ and $count \cdot min^{-1}$). This may be explained by the uneven sample (65 observations <72h vs 211 observations >72h) or the differing inclusion criteria (>10min [this study] vs >75min (27)). Prior match exposure within a tournament also negatively affected total distance in our study, regardless of time on pitch and the number of days between matches. However, the reduction per minute of match exposure is small ($0.01 m \cdot min^{-1}$) and perhaps not of practical importance to a coach. Consecutive match number had a significant effect on deceleration count; however, this was only observed in the first 2 matches and may not represent an effect of exposure during tournament. Overall, increasing time on pitch and fewer days between matches are associated with reduced match running, potentially due to the effects of acute or residual fatigue related responses.

The change in match running between halves may be affected by tournament-specific factors, including consecutive match number, days between matches, prior match exposure and time on pitch. The difference in time on pitch between halves was associated with total distance, with longer duration in the second half showing greater reductions in running distance. Such findings re-iterate the influence of time on pitch on total distance reported earlier, and highlight considerations on appropriate substitutions when required to maintain high match running loads (20). As prior match exposure increases there appears be a positive relationship with the change in total distance and change in high-speed running distance from first to second half. Hence, maintaining or increasing total distance and high-speed running in the second half may come with increased prior match exposure, which contrasts with the use of substitutions outlined earlier. Whilst speculative, this may suggest fitter or more seasoned players are selected to play and accumulate more match minutes in tournament, and may be a variable of interest for future models as has been reported in women's rugby sevens tournaments (8). Given the decrease in whole-match total distance, but smaller change between halves with increasing prior match exposure, it may also indicate players who play more matches employ pacing strategies to regulate match running in the first half; thereby attempting to maintain performance in the second half as tournaments progress (28). Of note, opposition quality may increase as tournaments progress during knock-out phases and given the opposition affects match running (27), this may contribute to the observed results. Whilst the above relates to total distance and high-speed running, very high-speed running, accelerations and decelerations were highly variable between consecutive matches, without any obvious decline; re-enforcing the role of pacing strategies and the need for future exploration alongside other factors (e.g., match outcome, opponent quality, environment(27)). Finally, more recovery time ($\geq$8 days which is unlikely in tournaments) resulted in significantly less decline in acceleration and deceleration counts, which may

reflect maintenance of these high metabolic and mechanical demands given the longer recovery time between matches (13, 22). However, whilst the decline in decelerations was improved with ≥8 days recovery compared to 4-7 days, interestingly no significant difference to ≤3 days was found. Of note, the change in running between halves models' explained variance (R^2) was low, particularly in the change in high-speed and very high-speed running models (0.103 and 0.189 respectively), suggesting other factors (match outcome, opponent quality, environment (27)) may have a larger influence and should be considered when interpreting the results.

The current study re-iterates previous research showing independent effects of days between matches, prior match exposure, consecutive match number and time on pitch on match running (8, 14, 20, 29). Novel to this study is the collective effect of these tournament factors given over half the models were predicted by multiple variables. For example, total distance was predicted by three factors and was the model with the greatest variance explained (R^2 = 0.627), thus days between matches, prior match exposure and time on pitch should be accounted for by practitioners when considering the total distance run by a player during tournament, especially on return to clubs (i.e., players returning to their domestic league competition club following an international tournament with their national team). High-speed and very high-speed running are perhaps the most important match running variables given the association to tournament placing (24) and goal scoring opportunities (7). Thus, the negative effects on high-speed and very high-speed running when more matches are played within 3 days is an obvious consideration. Such interplay between tournament variables on match running outcomes can help guide practitioner approaches to player exposure and preparation, especially using days between matches and time on pitch as a guide.

Whilst this study is novel in its approach to analyzing influences of tournament specific factors on female international soccer player match running, it should be noted the data belongs to one national team limiting the generalization of the findings. However, the different tournaments encompassed various coaches, differing tactics, and playing styles. Whilst tactical and situational factors were not analyzed as they were not the focus of the study, player position and tournament were accounted for. Our inclusion criteria >10min (as opposed to >75min or full matches (6, 27)) resulted in a greater number of observations but also allowed us to analyze the effect time on pitch on match running. Due to the nature of the sample size, we were unable to compare 3 days of recovery to 4 or 5 days which are frequently scheduled in international tournaments and may be of interest to future research. The results should be interpreted with caution as whilst statistically significant differences were found, practical application to individual players and teams should be considered e.g., a reduction in whole-match relative total distance by $2m \cdot min^{-1}$ following 200min played in a tournament may not be a concern.

Overall, time on pitch and fewer days between matches are associated with reduced match running and may have implications for player fatigue. These results are perhaps unsurprising, however, they highlight the statistically and practically significant reductions in tournament match running that exist. Conversely, players minimize reductions in match running between halves as tournaments progress (increasing match exposure), potentially indicating players employing pacing strategies. Understanding the effects of, and interaction between, these factors in consideration of each player and matches context can guide practitioners in their decision making to minimize reductions in match running and the change in match running between halves.

PRACTICAL APPLICATIONS

- Practitioners can use days between matches (≤3 days), increasing time on pitch and higher prior match exposure variables to inform the likely extent of change in match running demands throughout a tournament.
- Practitioners should expect match running to decrease with increasing time on pitch, and utilise this to aid match fitness training prescription.
- Fewer days between matches, increasing time on pitch and higher match exposure can be used to help plan fatigue monitoring, recovery strategies and squad rotation.

ACKNOWLEDGEMENTS

We thank the players, coaches, and support staff of the Australian women's national soccer team. We also thank Football Australia for their support of this study. The authors are all employed by Football Australia, though declare no potential conflict of interest relevant to the content of this article. There has been no financial assistance with the project. This study does not constitute endorsement of the product by the authors or the NSCA.

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448 **Figure legends**

449 Figure 1. Relationship between whole match distanced-based relative GPS variables ([1A]
450 total distance, [1B] high-speed running distance, [1C] very high-speed running distance) and
451 the fixed effects from the stepwise selection of predictors.

452

453 Figure 2. Relationship between whole match count-based relative GPS variables ([1A]
454 acceleration count, [1B] deceleration count) and the fixed effects from the stepwise selection
455 of predictors.

456

457 Figure 3. Relationship between change in distanced-based relative GPS variables between
458 halves ([1A] change in total distance, [1B] change in high-speed running distance, [1C]
459 change in very high-speed running distance) and the fixed effects from the stepwise selection
460 of predictors.

461

462 Figure 4. Relationship between change in count-based relative GPS variables between halves
463 ([1A] change in acceleration count, [1B] change in deceleration count) and the fixed effects
464 from the stepwise selection of predictors.