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How did match running performance change after an extra time match during FIFA 2022 World Cup and 2023 Women`s World Cup?

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Abstract

Objective This study aimed to explore the changing characteristics of running performance before and after extra time matches (ET) at the World Cup under new substitution rules and in special seasonal periods.

Methods Match running data of starting players who played ET compared to matches before and after the ET matches from the FIFA 2022 World Cup and the FIFA 2023 Women's World Cup were used for the analysis by using repeated-measures ANOVA.

Results Most of the relative running distance per minute for the ET match was lower than the pre and post ET match in both men and women World Cups. However, no significant differences ($p > 0.05$) were found between pre and post ET matches neither in men's nor women's World Cups, except total distance and low speed running distance per minute for men`s football ($p < 0.05$). Significant interaction effects of gender × match (ET/Post-ET) were found in total distance, walking and jogging distance, low speed running distance and high-speed running distance per min ($p < 0.05$). In contrast, no significant interaction effects were found in moderate speed running distance, sprint distance, number of high-speed running bouts, number of sprints per min and top speed ($p > 0.05$).

Conclusion The present findings revealed that players display limited fatigue and can maintain running performance in the match after extra time matches across both genders during World Cups with 4–5 days between matches. Coaches should continue to focus on approaches to reduce fatigue and speeding up athlete recovery after extra time matches in international tournaments.

Keywords Football, Extended time, Fatigue, Recovery, Performance analysis

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Introduction

Football is a physically demanding sport that requires athletes to perform at their peak for extensive periods of time [1, 2]. Matches can be physically demanding, lasting 90 min or more, and players are frequently competing in multiple matches within a short timeframe. One of the most challenging scenarios for modern footballers is playing a match that extends into extra time (ET) in international tournaments, totaling 120 min of intense physical exertion [3]. This prolonged effort can have a significant impact on players' physical performance in subsequent matches, affecting factors such as fatigue, muscle soreness, and injury risk [4]. Since the first World Cup in 1930, 27.4% of matches have gone to ET and 47.6% of the top four teams have played at least one ET match, and since 1992 as many as 89.2% of the top four teams has taken part in ET matches. Various studies have confirmed that ET has a detrimental effect on an athlete's fitness, hormone levels, respiratory exchange ratio and RPE [5–8], which can have a negative impact on subsequent matches. More recently, a study found that each additional minute of prior game exposure time and time on the field could reduce next match physical performance [9]. Thus, it is important to know to what extent ET influences match performance to help practitioners get more insight into this topic.

However, to the best of our knowledge, only one study has investigated how 120-min matches influence match performance in the next match using official match data. By physical performance analyses from the 2018 World Cup of four key players playing 3 consecutive matches of 120 min for the Croatian National Team, Kołodziejczyk et al. found that there was no fatigue effect on these players [10]. Reasonable recovery measures and training schedules may be the reason why athletes did not show differences in physical performance over the three matches. Nevertheless, there are some limitations to the findings due to the small sample size and the special circumstance of being three consecutive ET matches.

During the knockout stage, teams are on a congested schedule, and even 90-min matches during this period could lead to a decline in the athlete's physical performance [11]. When players are involved in 120-min matches, there is an extraordinary accumulated load, a greater muscle glycogen utilization and glycogen depletion in a large proportion of the individual muscle fibres [12], along with a significant neuromuscular fatigue [5]. Moreover, studies have shown that creatine kinase (CK) still above 500u·l^{-1} 48 h after a 120-min game [8], and that athletes experienced a decline in running performance and a lack of glycogen recovery during a 3-day period between two high-level 120-min friendly games [13]. Despite a big difference in the level of competition and match activities on one hand, and more days between the World Cup games on the other hand [10], the current evidence may still suggest that ET may have negative effects on subsequent match performance. Besides, the World Cup in previous studies used a 3-substitute rule, while the most recent World Cups have changed to a 5-substitute rule, which raises the intensity of the game [14, 15] and may further increase the physical exertion on the starters who play ET, making their post-game recovery more challenging. It is thus worthwhile to analyze the impact of ET in the World Cup under the new substitution rule.

In addition, most ET studies have addressed male athletes and there is a lack of research on female athletes. Thus, some studies have found that male and female athletes have different fatigue, technical and running profiles during matches [16–18]. Moreover, female and male athletes have different recovery characteristics due to differences in training status, competition load characteristics, and physiological and menstrual cycle effects [19], which means that male and female athletes may have different levels of fitness at the start of the next game after ET match. In fact, studies point out that women are more resistant to fatigue and recover faster because they have better muscle oxidative metabolism [20, 21]. It is therefore necessary to explore the effects of ET on the performance of female soccer players.

Therefore, by using the data of recent men's and women's World Cups, the purpose of this study was two-fold; firstly, to investigate the effect of extra time on athletes' physical performance in the game, and secondly, to explore the potential differences in the maintenance running performance for elite male and female footballers.

Methods

Sample

Physical performance in the FIFA 2022 World Cup and the FIFA 2023 Women`s World Cup were used for analysis in this study. All the physical performance data is open-access and was obtained from the FIFA official website (https://www.fifatrainingcentre.com/en/fwc2022/post-match-summaries/post-match-summary-reports.php and https://www.fifatrainingcentre.com/en/game/tournaments/fifa-womens-world-cup/2023/match-report-hub/post-match-summary-reports.php). The original data were collected by a multi-camera optical tracking system (TRACAB Gen5, ChyronHego), which was captured by 25 Hz high-definition cameras and has been shown to have a good validity [22]. The 2022 World Cup and the 2023 Women's World Cup have comparable data as they use the same system. Since we used public data and there are no additional subjects, no ethical certification is required.

Procedure

In order to analyze the fatigue effect of ET, firstly, we chose players who played ET and compared their data from the game before and the game after ET match. Secondly, we compared post ET match data increase ratios for different genders. Only data from starting players who played more than 60 min in the pre/post-ET game and as starters also played in the ET were used in the analysis. In the 2022 World Cup, Croatia had two consecutive ET matches, and we used the latter as the ET match data and the data before the first ET match as the pre-ET match data. In addition, one of the matches before ET matches was played with a significant squad rotation (more than 50% of the starting athletes were unconventional starters: Sweden vs. Argentina in the 2023 Women's World Cup), so we used the data from the one match further back in the competition of Sweden national team for our analysis. Data for goalkeepers were excluded due to their positional specificity. Thus, a total of 44 players (15 for male and 29 for female) in 21 matches (9 for male and 12 for female) running data were final included for analysis. Athletes' running distances were standardized based on their actual playing time including stoppage time. Meanwhile, the length of stoppage time for regular game time for the sample included in our study was in the same range (9.7 ± 2.4 min), despite a significant increase in extra time in the 2022 and 2023 FIFA world Cup. Detail of the speed zones and data analysis are shown in Table 1, in which the male and female athletes overlapped only in the walking and jogging zones. This division of speed zones and gender differences has been shown to better reflect players' capacities [23].

Statistics analysis

Data are expressed as mean ± standard deviation. Normality was checked by the Kolmogorov-Smirnov test combined with Q-Q plots. A one-way repeated-measures ANOVA with Tukey post-hoc test was used to compare differences in running before and after overtime. A two-way repeated-measures ANOVA was used to analyse the effect of gender and match (ET/Post-ET) on running performance.Cohen's d and partial eta squared (η_p^2) were used to evaluate the effect size (ES) and were classified as trivial ($d \le 0.2$), small ($0.2 < d \le 0.6$), moderate ($0.6 < d \le 1.2$), large ($1.2 < d \le 2.0$), very large ($d > 2.0$), for Cohen`s d; small ($0.01 < \eta_p^2 \le 0.06$), moderate ($0.06 < \eta_p^2 \le 0.14$) and large ($\eta_p^2 > 0.14$) for η_p^2, respectively. Data were processed using SPSS 26.0 (IBM, Chicago, USA). A significant level was set as $\alpha = 0.05$.

Results

Figure 1 shows the results of match running performance change across pre-ET matches, ET matches and post-ET matches in the 2022 Men's World Cup. Significant differences were found in total distance (TD), walking and jogging distance (WJD), low speed running distance (LSRD), moderate speed running distance (MSRD), and high speed running (HSR) counts across the three matches ($p<0.05$, $\eta_p^2 = 0.283–0.649$), with WJD, MSRD, and HSR counts in ET match being significantly lower than pre ($p < 0.05$, $d = 0.42–0.86$), MSRD, and HSR counts in ET match being significantly lower than post-ET match ($p < 0.05$, $d = 0.47–0.67$), TD in ET match and post-ET game being significantly lower than pre-ET ($p < 0.05$, $d = 0.46–0.56$), and LSRD in pre-ET match being significantly higher than post-ET match ($p < 0.05$, $d = 0.42$). No difference was found in other metrics across the three matches ($p > 0.05$, $\eta_p^2 = 0.021–0.173$).

Figure 2 shows the results of match running performance change across pre-ET matches, ET matches and post-ET matches in the 2023 Women`s World Cup. Significant differences were found in TD, WJD, LSRD, MSRD, HSRD counts, and TS, across the three matches ($p<0.05$, $\eta_p^2 = 0.140–0.473$), with TD, LSRD, MSRD and HSR counts in the ET match being significantly different from pre ($p < 0.05$, $d = 0.43–0.77$) and post-ET match ($p < 0.05$, $d = 0.33–0.56$), and WJD and TS in the ET match being significantly higher than pre-ET match ($p < 0.05$, $d = 0.40–0.71$). No difference was found in other metrics across three matches ($p > 0.05$, $\eta_p^2 = 0.010–0.027$).

Table 2 shows the two-way repeat ANOVA results of different genders and matches (ET/post-ET). It shows

Table 1 Definition about variables used in the study

Variables	Definition
Relative total distance (TD)	Total distance covered per minute
Relative walking and jogging distance (WJD)	Walking and jogging distance covered per minute (0–7 km/h)
Relative low speed running distance (LSRD)	Low speed running distance covered per minute (M: 7–15 km/h; F: 7–13 km/h)
Relative moderate speed running distance (MSRD)	Moderate speed running distance covered per minute (M: 15–20 km/h; F: 13–19 km/h)
Relative high-speed running distance (HSRD)	High-speed running distance covered per minute (M: 20–25 km/h; F: 19–23 km/h)
Relative sprint distance (SD)	Sprint distance covered per minute (M: ≥25.0 km/h; F: ≥23 km/h)
Relative number of high-speed running (No. HSR)	Times of high-speed running per minute
Relative number of sprints (No. HSR)	Times of sprint per minute
Top speed (TS)	Maximal speed reached during a match

Legend: M = male, F = female

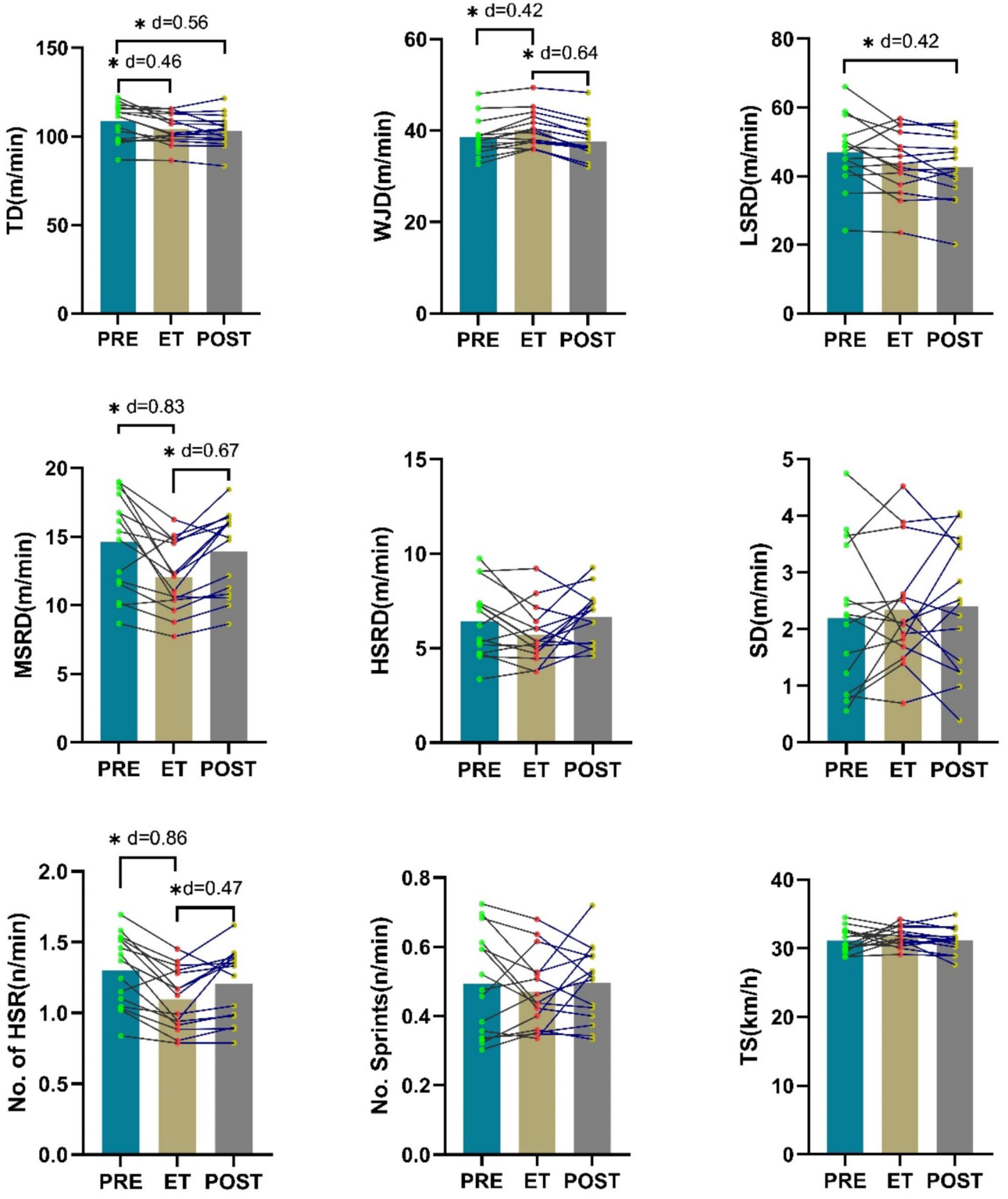

Fig. 1 Comparison of physical performance during pre, post and ET match in the 2022 World Cup. Notes: * denotes significant difference between two groups: ET = Extra match; PRE = the match before extra match; POST = the match after extra match; TD = Relative total distance per min; WJD = Relative walking and jogging distance per min; LSRD = Relative low speed running distance per min; MSRD = Relative moderate speed running distance per min; HSRD = Relative high speed running distance per min; SD = Relative sprint distance per min; No. HSR = Relative number of high-speed running per min; No. sprints = Relative number of sprint per min; TS = Top speed

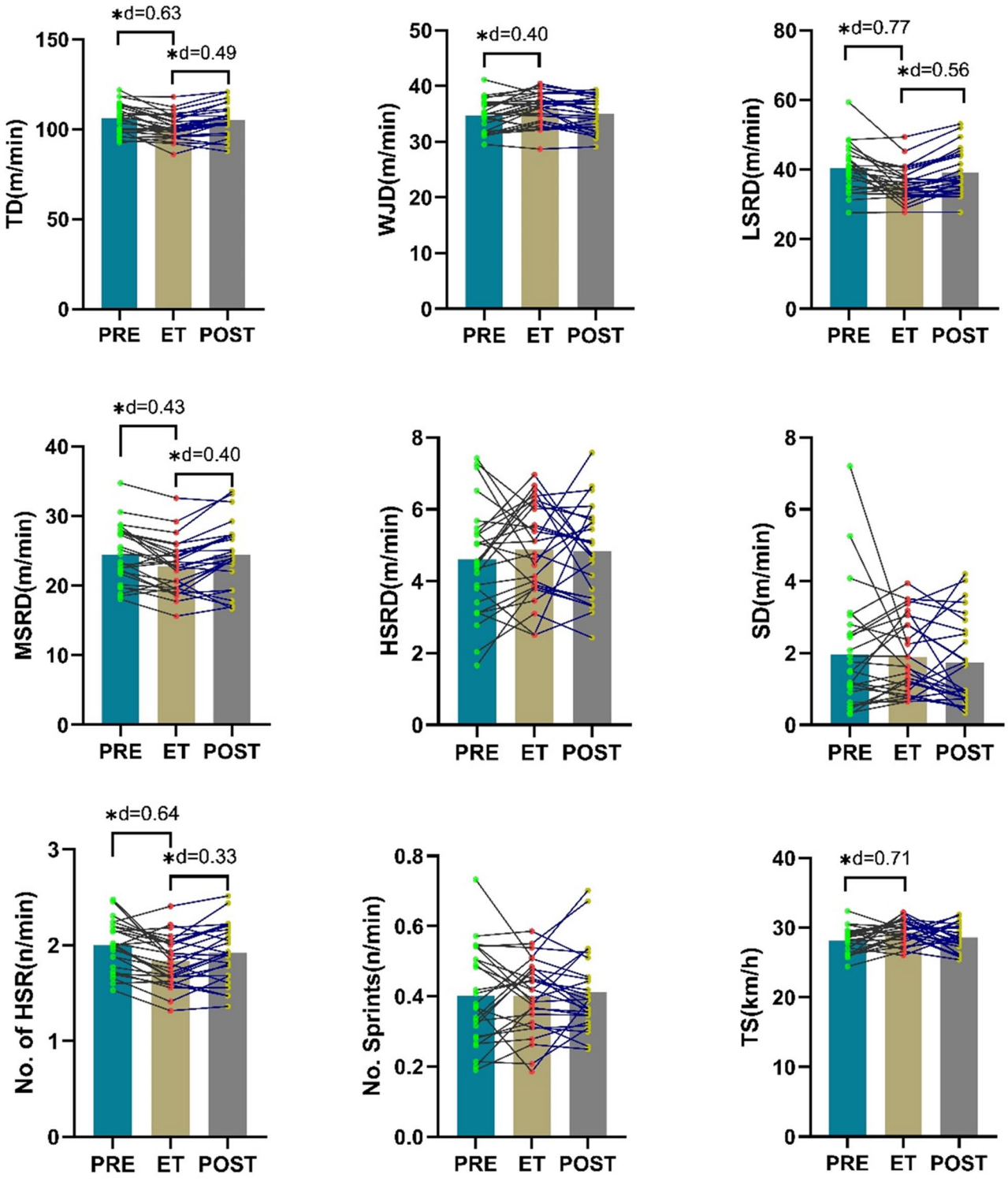

Fig. 2 Comparison of physical performance during pre, post and ET match in the 2023 Women`s World Cup. Notes: * Denotes significant difference between two groups: ET = Extra match; PRE = the match before extra match; POST = the match after extra match; TD = Relative total distance per min; WJD = Relative walking and jogging distance per min; LSRD = Relative low speed running distance per min; MSRD = Relative moderate speed running distance per min; HSRD = Relative high speed running distance per min; SD = Relative sprint distance per min; No. HSR = Relative number of high-speed running per min; No. sprints = Relative number of sprint per min; TS = Top speed

Table 2 Physical performance relation to gender and matches in the 2022 World Cup and 2023 Women`s World Cup

	Gender	ET	Post-ET	Interaction effect Gender × Match	Main effect	
					Gender	Match
TD (m/min)	Male	104.3 ± 8.5	103.2 ± 9.1	$p = 0.002$	$p = 0.687$	$p = 0.089$
	Females	101.0 ± 6.7	104.4 ± 8.5	$\eta_p^2 = 0.201$	$\eta_p^2 = 0.004$	$\eta_p^2 = 0.067$
WJD (m/min)	Male	40.2 ± 3.9	37.6 ± 4.2	$p = 0.001$	$p = 0.003$	$p = 0.000$
	Females	35.9 ± 2.8	35.4 ± 3.1	$\eta_p^2 = 0.251$	$\eta_p^2 = 0.190$	$\eta_p^2 = 0.438$
LSRD (m/min)	Male	44.0 ± 9.3	42.8 ± 9.6	$p = 0.001$	$p = 0.009$	$p = 0.217$
	Females	35.9 ± 4.7	38.6 ± 6.5	$\eta_p^2 = 0.240$	$\eta_p^2 = 0.153$	$\eta_p^2 = 0.036$
MSRD (m/min)	Male	12.0 ± 2.6	13.9 ± 3.0	$p = 0.583$	$p = 0.000$	$p = 0.000$
	Females	22.6 ± 3.7	24.1 ± 4.6	$\eta_p^2 = 0.007$	$\eta_p^2 = 0.659$	$\eta_p^2 = 0.340$
HSRD (m/min)	Male	5.7 ± 1.5	6.6 ± 1.4	$p = 0.040$	$p = 0.000$	$p = 0.056$
	Females	4.8 ± 1.3	4.8 ± 1.3	$\eta_p^2 = 0.096$	$\eta_p^2 = 0.256$	$\eta_p^2 = 0.084$
SD (m/min)	Male	2.3 ± 1.0	2.4 ± 1.2	$p = 0.624$	$p = 0.050$	$p = 0.873$
	Females	1.8 ± 1.1	1.7 ± 1.2	$\eta_p^2 = 0.006$	$\eta_p^2 = 0.089$	$\eta_p^2 = 0.001$
No. HSR (times/min)	Male	1.10 ± 0.22	1.21 ± 0.25	$p = 0.526$	$p = 0.000$	$p = 0.002$
	Females	1.82 ± 0.27	1.90 ± 0.29	$\eta_p^2 = 0.010$	$\eta_p^2 = 0.654$	$\eta_p^2 = 0.212$
No. sprints (times/min)	Male	0.47 ± 0.11	0.50 ± 0.11	$p = 0.640$	$p = 0.014$	$p = 0.199$
	Females	0.40 ± 0.11	0.41 ± 0.11	$\eta_p^2 = 0.005$	$\eta_p^2 = 0.135$	$\eta_p^2 = 0.039$
TS (km/h)	Male	31.7 ± 1.4	31.2 ± 1.8	$p = 0.751$	$p = 0.000$	$p = 0.074$
	Females	29.4 ± 1.7	28.6 ± 1.8	$\eta_p^2 = 0.002$	$\eta_p^2 = 0.454$	$\eta_p^2 = 0.074$

Notes: ET = Extra match; TD = Relative total distance per min; WJD = Relative walking and jogging distance per min; LSRD = Relative low speed running distance per min; MSRD = Relative moderate speed running distance per min; HSRD = Relative high speed running distance per min; SD = Relative sprint distance per min; No. HSR = Relative number of high-speed running per min; No. sprints = Relative number of sprint per min; TS = Top speed

that a significant main effect ($p < 0.05$, $\eta_p^2 = 0.089–0.654$) of gender was found in all metrics except TD per min ($p > 0.05$, $\eta_p^2 = 0.004$). No significant main effect of match was found in all metrics ($p > 0.05$, $\eta_p^2 = 0.001–0.084$) except WJD, MSRD and number of sprints per min ($p < 0.05$, $\eta_p^2 = 0.212–0.438$).

Significant interaction effects (gender × match) were found in TD, WJD, LSRD, HSRD ($p < 0.05$, $\eta_p^2 = 0.096–0.251$). By contrast, no significant interaction effect was found in MSRD, SD, number of HSR, number of sprints and top speed (TS) ($p > 0.05$, $\eta_p^2 = 0.002–0.010$).

Discussion

This study analyzed the change in running performance in the next match for all athletes who took part in extra time matches (ET) by using data from the most recent World Cups for men and women. We found that despite an attenuated MSRD and HSR per min in the ET game, these metrics were maintained in the post-ET games, suggesting no residual fatigue carried from ET into post-ET. Additionally, there was a difference in the maintenance characteristics of running performance of the men and women after the ET.

Firstly, the results show that most running intensity data were lower in ET matches compared to the 90-min matches. This finding suggests that athletes experienced fatigue during the 30-min ET phase, consistent with previous research findings [8, 12, 24]. One of the causes of fatigue during the 30-min ET phase may be glycogen depletion in a high proportion of the type 1 and type 2 muscle fibres. Studies using the muscle biopsies technique, have found that muscle homogenate glycogen levels dropped to 236–266 mmol/kg dw after 90 min and further to 186 mmol/kg dw after ET [12], and that one-half to three-fourth of the individual type 1 and type 2 fibres were glycogen depleted after 90 and 120 min matches [12, 25, 26]. Moreover, muscle glycogen levels below 250 mmol/kg dw can negatively affect sarcoplasmic reticulum function [27] and may lead to impaired glycolysis rates [28], suggesting that athletes do not have energy deficits at regular times but spend most of the ET in a state of impaired metabolic functioning, and thus diminished running performance in the ET. In addition, a more pronounced dehydration and fatigue of central mechanisms in the ET, partly related to potential hypoglycemia, may also have contributed to the decline in running performance [12].

In the present study, we did not find a significant decrease in running performance in the match after ET. The main reason may be that the athlete's glycogen is effectively restored before the next match. In the study by Krustrup et al. [29], athletes' glycogen returned to baseline levels in 72 h after competition, also when it was below 200 mmol/kg dw after match play. More recently, a statistical model developed by Brown et al. using data from four international tournaments found that running performance was reduced only when the interval between matches was less than or equal to three days [9]. Whereas the breaks between games in our study were on 4 or 5 days, this may be one of the major reasons

why no drop in running performance was found. Furthermore, with the development of sports science, high-level teams will be equipped with more comprehensive rehabilitation and nutritional professionals and equipment to promote faster recovery of athletes [30, 31]. For example, according to the Croatian team's fitness coach, they have a rigorous and comprehensive recovery program and means, and thus were able to play three consecutive 120 min matches without significant fatigue [10]. Study also shown that players in the top ranked teams maintain their running performance in the whole tournament stage during the 2014 FIFA World Cup [32]. Moreover, it was shown that no difference in running performance between group and knock-out stage in FIFA 2023 Women`s World Cup except LSRD [33]. Overall, it suggests that a four to five days interval after the World Cup ET matches we analysis is sufficient to allow athletes to rehabilitate their fitness and practitioners need to pay attention to help athletes accelerate regeneration based on their level of fatigue after ET match [4].

Finally, the analysis of the interaction effect (gender × match) showed that men's and women's soccer players had some differences in ET fatigue and maintenance characteristics of running performance during the 2022 and 2023 Women`s World Cup. One reason could be that women athletes typically have better fatigue resistance and recovery because they have better muscle oxidative metabolism [20, 21], which can be shown in the interaction analysis where the women increase more and men decrease in TD and WJD in the post ET match. In fact, it has been shown that female soccer players have lower plasma stress markers during World Cup [17]. Moreover, the 2022 World Cup was played in mid-season and the 2023 Women`s World Cup was played out of season (most of the athletes we analyzed are from European teams), thus men athletes had already experienced a congested period in the league matches prior to the World Cup and had greater accumulated fatigue [34, 35], making their recovery more challenging. Another reason could be the climate, as the 2022 Qatar World Cup had greater temperatures and humidity. By simulating the climate conditions of Qatar, Konefał et al. found that athletes' fatigue thresholds occurred at lower intensities [36]. And a recent study using data from German Bundesliga 1 and 2, Japanese J-League, and Turkish SüperLig found that warmer environmental conditions were associated with lower running performance [37].

One of the limitations of this study is that the athletes were not categorized into different positions. Besides, factors such as opponent, team tactics, pacing strategies, physical fitness of players, match location and score line could also play an important role in running performance. For example, player in fourth division Brazilian Championship will running more when facing strength opponent [38]. In contrast, running performance was similar irrespective of opponent`s quality in UEFA Champions League [39]. And players tend run more in drawing to winning match in UEFA Champions League [40]. Nevertheless, due to the limited sample size, we were unable to combine these variables in our analysis. Future research needs to explore the fatigue and recovery characteristics of the above metrics to get a deeper insight into the influence of ET.

Conclusion

In conclusion, this study described the dynamics of running performance before and after ET in both men's and women's World Cup matches, utilizing data from the 2022 and 2023 tournaments. The findings revealed that players display limited fatigue and can maintain running performance in the match after ET matches. Notably, men's and women's soccer players had some differences in ET fatigue and maintaining characteristics of running performance when comparing the 2022 Men's World Cup and the 2023 Women`s World Cup.

These insights shed light on the fatigue and maintenance characteristics of running performance associated with ET, offering valuable guidance for practitioners and coaches. Understanding these characteristics is pivotal in continuing the use of effective strategies to mitigate athlete fatigue and facilitate swift recovery, ultimately enhancing running performance in subsequent matches following ET, or even multiple ET occurring in international tournaments with up to 16 knockout matches. Practitioners need to understand precisely the impact of overtime on athletes' running characteristics and rationally arrange training and recovery after overtime. On the one hand, it is necessary to promote the recovery of athletes' fatigue; on the other hand, recovery should not be overemphasized, and the technical and tactical training and conditioning before the post-ET match should also be properly conducted.

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Author contributions

Concept and design: Xiaobin Wei, Rongqiang Pu and Peter Krustrup; Data analysis and interpretation: Xiaobin Wei and Nianci Wang; Drafting of the article: Xiaobin Wei; Critical revision of the article for important intellectual content: Peter Krustrup and Paweł Chmura; All the authors approved the final article.

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Data availability

Data can be requested from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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