GAME-INDUCED FATIGUE PATTERNS IN ELITE FEMALE SOCCER

PETER KRUSTRUP,1 METTE ZEBIS,2 JACK M. JENSEN,1 AND MAGNI MOHR1

1Department of Exercise and Sport Sciences, University of Copenhagen, Copenhagen, Denmark; and 2Sports Medicine Research Unit, Copenhagen University Hospital, Copenhagen, Denmark

ABSTRACT

Krustrup, P, Zebis, M, Jensen, JM, and Mohr, M. Game-induced fatigue patterns in elite female soccer. J Strength Cond Res 24(2): 437–441, 2010—The purpose was to examine the fatigue pattern of elite female soccer players after competitive games. Soccer players (n = 23) from the Danish women Premier League performed a countermovement vertical jump test, a repeated 30-m sprint test, and the Yo-Yo intermittent endurance level 2 (Yo-Yo IE2) test at rested state and after a competitive game. Average heart rate during the game was 86 ± 1% of maximal heart rate with no differences between halves. Blood lactate was 5.1 ± 0.5 mmol/L after the first half, which was higher (p < 0.05) than after the second half (2.7 ± 0.4 mmol/L). Yo-Yo IE2 performance was 484 ± 50 m after the game, which was 62% lower (p < 0.05) than at rested state (1,265 ± 133 m). Average sprinting time of three 30-m sprints was 5.06 ± 0.06 seconds after the game, which was 4% slower (p < 0.05) than at rest (4.86 ± 0.06 seconds). No game-induced effect was observed on vertical jump performance. Significant inverse correlations were observed between Yo-Yo IE2 test performance and fatigue index during the repeated sprint test both at rest (r = −0.76, p < 0.05) and after the game (r = −0.66, p < 0.05). The study demonstrates that the type of fatigue that occurs after a female soccer game does cause marked impairment in intense intermittent exercise and repeated sprint performance but does not affect vertical jump performance. These findings support the notion that decrements in distance covered by sprinting and high-speed running toward the end of elite female games are caused by fatigue.

KEY WORDS intermittent exercise performance, sprint, jump, blood lactate, football

INTRODUCTION

The distances covered by high-intensity running have been proposed to be of great importance for performance in elite soccer because this parameter clearly distinguishes between top class and high-level elite players (19,20). Significant reductions in sprinting and high-speed running have been observed toward the end of elite games for men (1,20) and women (17,19). It has been discussed whether this phenomenon is a result of physiological fatigue or due to tactical and psychological factors. The findings that the amount of high-intensity running in the last 15-minute period is correlated with training status (17) and that replacement players perform 25% more high-intensity running and 63% more sprinting in the last quarter of the game than players playing the entire game (20) support the notion that the lowered match intensity is caused by fatigue. However, to provide direct evidence of development of fatigue during elite soccer games, it is necessary to combine motion analyses with performance tests performed before and after games.

Sprint tests performed before and after elite male games have demonstrated that peak running speed and repeated sprint performance deteriorate considerably during games (18,22,26). However, it is unknown to what extent elite female soccer players are affected by a competitive game. The etiology of fatigue is complex and is highly dependent on exercise mode (8). Thus, performance may be attenuated during a repeated sprint test after a game as stated above, but the degree of game-induced fatigue may develop differently in other exercise tasks. For example, Bangsbo and Mohr (4) showed that peak sprinting speed was hampered in the final 15-minute interval of a game, indicating that the ability to develop peak power is also impaired toward the end of a game. On the other hand, discrepancy seems to exist regarding the game-induced effect on activities demanding a high rate of force development in men (10,12,23,24). For example, studies show significant impairment in jump performance after a simulated soccer game (23), whereas others observe no change immediately after a soccer game compared with rested state (12). Thus, fatigue resistance during intense intermittent exercise, repeated sprints, and countermovement jumps may be differently challenged by a competitive female soccer game.
It is well described that the physical match performance is related to training status of female soccer players (17), male soccer players (15,20), and soccer match officials (14,16). However, it is still to be investigated whether the match-induced decrements in test performances are related to training status.

Thus, the aim of the present study was to elucidate the type of fatigue that occurs after an elite female soccer match and the possible connection between game-induced fatigue and training status.

**Methods**

**Experimental Approach to the Problem**

To study fatigue patterns and physiological response in elite female soccer games, 23 players in Danish League top teams (ranks 1–5) were investigated during competitive matches between top teams (ranks 1–5). To determine the physical status of the players and to investigate various types of game-induced performance decrements, the players performed an intense intermittent shuttle run test, a repeated sprint test, and a countermovement jump test before and after a game. The investigated matches were played during the 2006 competitive season, with the scores being 1-0, 3-1, and 2-2.

**Subjects**

A total number of 23 elite female soccer players from the Danish top league took part in the study. Their age, height, weight, and body fat content were 23 (range: 18–29) years, 60.1 (53.3–69.5) kg, 1.69 (1.59–1.80) m, and 18.5% (12.7–27.6%), respectively. In addition, the players had a Yo-Yo intermittent endurance level 2 (Yo-Yo IE2) performance of 2,123 ± 90 m, an incremental treadmill test performance of 5.2 ± 0.2 minutes, and a VO2max of 52.3 ± 1.3 mlO2·kg−1·min−1. The players had been active soccer players for 10–15 years and had been elite players for at least 3 years, with 4–5 weekly training sessions. The players were representing all outfield positions. The players were fully informed of all experimental procedures and risks before giving their written informed consent to participate. The study conforms to the code of ethics of the Declaration of Helsinki and was approved by the Ethics Committee of Copenhagen and Frederiksberg municipalities.

**Procedure**

Fourteen players performed a repeated sprint test before and immediately after competitive games, consisting of three 30-m sprints, separated by a 25-second period of active recovery, during which the players jogged back to the starting line (11,18). Thus, the test lasted ~1 minute. The sprint times were recorded by infrared light sensors, having a precision of 0.01 seconds (Time It; Eleiko Sport, Halmstad, Sweden). On another occasion, the same players performed a countermovement jump test before and after a game. The jump test consisted of 3 countermovement jumps with the hands fixed on the hips and was performed on a jumping mat (Time It; Eleiko Sport). The jumps were interspersed with 30-second rest periods, and the best jump was used as the test result. The same players performed a Yo-Yo IE2 (2,6) and an exhaustive incremental treadmill test (14). During the treadmill test, maximal pulmonary oxygen uptake (VO2max) was determined as previously described (14–17). In addition, another group of players (n = 10) carried out the Yo-Yo IE2 test at rest and within 3 minutes after a competitive game. The coefficient of variation in test-retest Yo-Yo IE2 scores has been shown to be 7% (6).

Heart rate was recorded in 5-second intervals during 3 competitive games (n = 23) using a Polar Vantage NV heart rate monitor (Polar, Electro Oy, Kempele, Finland). The chest monitor and wrist receiver, weighing ~100 g, was placed on the player approximately 45 minutes before kickoff. A finger prick blood sample was collected 1–2 minutes after the end of each half in 2 games for 15 players playing the entire game as well as after the game for 4 substitutes. Within 10 seconds of sampling, 100 μl of blood was hemolyzed in 100 μl of ice-cold triton X-100 buffer solution and later analyzed for lactate and glucose using the YSI 2300 lactate analyzer (Yellow Springs, OH, USA (9)).

**Statistical Analyses**

Game-induced changes in Yo-Yo IE2 and jump performance and differences in blood lactates between halves were evaluated by the Student's paired t-test. The 1-way analysis of variance (ANOVA) with repeated measures was used to test heart rates changes during the game. The 2-factor ANOVA for repeated measurement was used to evaluate differences in repeated sprint performance. When a significant interaction was detected, data were subsequently analyzed using a Newman-Keuls post hoc test. Correlation coefficients were determined and tested for significance using
Pearson’s product-moment test. Significance level was set to $p \leq 0.05$. Values are presented as mean $\pm$ SEM.

RESULTS

Physiological Response to Competitive Games
The average heart rate and peak heart rate during the game were $168 \pm 1$ and $194 \pm 2$ b-min$^{-1}$, respectively, corresponding to $86 \pm 1$ and $98 \pm 1\%$ of the maximal heart rate ($197 \pm 1$ b-min$^{-1}$). Average heart rate was not different between the first and second half ($170 \pm 1$ and $167 \pm 2$ b-min$^{-1}$, nonsignificant) or between any of the 15-minute periods (75–90 minutes: $171 \pm 2$ b-min$^{-1}$).

Blood lactates were higher ($p < 0.05$) after the first half compared with the second ($5.1 \pm 0.5$ vs. $2.7 \pm 0.4$ mmol-L$^{-1}$) (Figure 1). Blood glucose was $6.3 \pm 0.2$ and $5.5 \pm 0.2$ mmol-L$^{-1}$ after the first and the second half, respectively, with no difference between halves.

Performance After Competitive Games
The countermovement vertical jump height was $36 \pm 1$ (range: 31–43) cm after the game, which was not different from before the game ($35 \pm 1$ (30–41) cm; Figure 2A). Average sprint time for three 30-m sprints was $5.06 \pm 0.06$ seconds, which was slower ($p < 0.05$) than before the game ($4.86 \pm 0.06$ seconds). The first, second, and third sprint performed after the game was $3.9 \pm 1.0$, $4.2 \pm 0.7$, and $4.4 \pm 0.9\%$ slower ($p < 0.05$) than before the game (Figure 2B). The third sprint was slower ($p < 0.05$) than the first sprint both before and after the game (Figure 2B).

Yo-Yo IE2 test performance was $1,265 \pm 133$ m in rested state but had decreased ($p < 0.05$) to $484 \pm 50$ m after a game (Figure 3).

Correlations Between Test Variables
Peak sprint and vertical jump performance were correlated ($r = 0.60, p < 0.05$). Yo-Yo IE2 performance was correlated with $\dot{V}_{O2}\max$ ($r = 0.58, p < 0.05$), whereas no correlation was found between Yo-Yo IE2 performance and the best 30 m sprint time ($r = 0.02, \text{NS}$) or vertical jump performance ($r = 0.37, \text{NS}$). A significant inverse correlation ($p < 0.05$) was found between Yo-Yo IE2 performance and the fatigue index in the repeated sprint test both at rested state ($r = -0.76, p < 0.05$) and after the game ($r = -0.66, p < 0.05$). No correlation was found between $\dot{V}_{O2}\max$ ($r = 0.08–0.12, \text{NS}$) or %HR$\max$ ($r = 0.05–0.13, \text{NS}$) and the pre- and post-match repeated sprint fatigue index.
DISCUSSION

The present study provides direct evidence that repeated sprint and intense intermittent exercise performance is attenuated at the end of soccer games for female elite players, confirming that perturbations in work rate during the last phase of a game are caused by game-induced fatigue. In contrast to sprinting ability and intermittent exercise performance, jump performance was not compromised by the game, indicating that fatigue development in soccer is a highly specific phenomenon.

The physiological loading during the investigated elite female soccer games resulted in a reduced performance of three 30-m sprints for 13 of 14 players with an average reduction of more than 4%. The observed decrement appears to be somewhat higher than the 2–3% reduction determined for male players (18,22,26), which may be due to the fact that the present study investigated sprint performance after competitive games and not friendly games as in the other studies. However, it may also be due to differences in training status or gender-specific fatigue development (13). A game-induced impairment in intermittent exercise performance, as evaluated by the Yo-Yo intermittent endurance test, occurred for all the tested players with an average reduction of more than 60%. Such a drop in Yo-Yo IE2 performance is quite extreme and emphasizes that the type of fatigue that occurs in the late stage of a game has an extraordinary impact on recovery capacity during sustained exercise bouts interspersed by short recovery periods. Together, these observations provide evidence that the marked reductions in the number of high-intensity runs and the number of sprints toward the end of elite female soccer games (17,19) are related to development of fatigue. The degree of decrement in sprint and intermittent exercise performance during the game was, however, not related to training status expressed as maximal oxygen uptake, Yo-Yo IE2 performance, or sprint performance. In line with other studies showing that physically fit players perform more high-intensity running during the game (15,17,19,20,25) and have the same aerobic loading during games (17), this indicates that all players use their physical capacity during competitive games. Nonetheless, it was observed that the players having the highest Yo-Yo IE2 test scores had the lowest fatigue index in the repeated sprint test, also after the game, indicating a relation between training status and fatigue resistance.

Interestingly, jumping performance was shown to be unaffected after the game. This lack of difference in jump height does not seem to be related to a type 2 error. First, the average value was 1 cm higher (nonsignificantly) after compared with before the game. Second, none of the players had a lowering in jump performance after the game that was larger than 1 cm. Several studies using male players have investigated the effect on explosive single contraction activities after soccer games (12), soccer training (10), and simulated soccer protocols (23,24), but with contrasting results. In line with the present finding, Hoffman et al. (12) showed no change in jump performance immediately after a soccer game, whereas performance was impaired 24 hours later. Others have showed decrement in jump performance (23), but this was after a soccer-simulated exercise protocol. Thus, jumping performance does not seem to be deteriorated in the same manner as repeated sprint and intense intermittent performance, clearly indicating that the physiological mechanisms provoking fatigue may differ during the different types of exercise.

It has been suggested that fatigue toward the end of soccer games is related to the fact that muscle glycogen concentrations are substantially reduced (3,5,7,21,27,28) and that some individual fibers are depleted of muscle glycogen after games (18). In the present study, muscle glycogen was not determined but blood lactate was depleted of muscle glycogen after games (18,22,26), which may be due to the fact that the present study investigated sprint performance after competitive games and not friendly games as in the other studies. However, it may also be due to differences in training status or gender-specific fatigue development (13). A game-induced reduction in intermittent exercise performance, as evaluated by the Yo-Yo intermittent endurance test, occurred for all the tested players with an average reduction of more than 4%. Such a drop in Yo-Yo IE2 performance is quite extreme and emphasizes that the type of fatigue that occurs in the late stage of a game has an extraordinary impact on recovery capacity during sustained exercise bouts interspersed by short recovery periods. Together, these observations provide evidence that the marked reductions in the number of high-intensity runs and the number of sprints toward the end of elite female soccer games (17,19) are related to development of fatigue. The degree of decrement in sprint and intermittent exercise performance during the game was, however, not related to training status expressed as maximal oxygen uptake, Yo-Yo IE2 performance, or sprint performance. In line with other studies showing that physically fit players perform more high-intensity running during the game (15,17,19,20,25) and have the same aerobic loading during games (17), this indicates that all players use their physical capacity during competitive games. Nonetheless, it was observed that the players having the highest Yo-Yo IE2 test scores had the lowest fatigue index in the repeated sprint test, also after the game, indicating a relation between training status and fatigue resistance.

Interestingly, jumping performance was shown to be unaffected after the game. This lack of difference in jump height does not seem to be related to a type 2 error. First, the average value was 1 cm higher (nonsignificantly) after compared with before the game. Second, none of the players had a lowering in jump performance after the game that was larger than 1 cm. Several studies using male players have investigated the effect on explosive single contraction activities after soccer games (12), soccer training (10), and simulated soccer protocols (23,24), but with contrasting results. In line with the present finding, Hoffman et al. (12) showed no change in jump performance immediately after a soccer game, whereas performance was impaired 24 hours later. Others have showed decrement in jump performance (23), but this was after a soccer-simulated exercise protocol. Thus, jump performance does not seem to be deteriorated in the same manner as repeated sprint and intense intermittent performance, clearly indicating that the physiological mechanisms provoking fatigue may differ during the different types of exercise.
**Practical Applications**

In another study, we showed that the exercise intensity declines markedly toward the end of a female soccer game. The present study confirms that this decrement is due to fatigue development. This type of fatigue may relate to lowered muscle glycogen levels, and female soccer players should therefore follow qualified nutritional strategies in the days before games. The study also provides indications of an association between intense intermittent exercise performance and fatigue resistance after a game. Thus, fitness training of the female soccer player should aim at improving the ability to repeatedly exercise at a high intensity.

**Acknowledgments**

We thank the soccer players, their coaches, and clubs for their effort. The study was supported by Team Denmark (Team Danmark), The Danish Football Association (Dansk Boldspils-Union), and The Sports Research Council (Idraettens Forskningsråd).

**References**


