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ORIGINAL ARTICLE

The hurdling on home straight in the women 3000m steeplechase

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ABSTRACT

The 3000m steeplechase is an event in which athletes must clear 28 hurdles and 7 water jumps while competing for the fastest time. In this race, women must clear hurdles set at a height of 0.762 meters, whereas men face hurdles set at a height of 0.914 meters. There is a paucity of research on the 3000m steeplechase compared to other long-distance events. This study aimed to clarify the characteristics of hurdle clearance for the 3000m steeplechase. Investigating how to clear the hurdles on the home straight could significantly enhance race strategies and performance. Data were collected from the women's 3000m steeplechase races at Kanto intercollegiate race. 15 women's performances were analyzed. The 3000m steeplechase races were recorded by video camera. All jumps from participants were digitized using Kinovea (version 0.9.3). I focused on variables of three steps related to the three steps around hurdles, and comparisons were made among each lap. In terms of total clearance speed, we observed that lap4 had a lower speed than lap3, and lap7 had a higher speed than lap4. Before the increase in speed at the hurdle, there was an increase in the length of three steps in lap7. Athletes in the final lap took off from a longer distance and achieved a faster clearance speed. The step frequency before hurdle clearance was higher in lap1 and lap2 than in lap4, lap5, lap6, and lap7. In addition, step frequency after hurdle clearance did not differ among laps and was lower than before hurdle clearance. Fatigue might be a contributing factor to this decline in step frequency before hurdle clearance. It would be advantageous for athletes to consciously increase their step frequency when approaching the next hurdle. The present study provided practical evidence for hurdle clearance of 3000m steeplechase.

Keywords: Performance analysis, Take-off distance, Landing distance, Hurdle clearance.

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INTRODUCTION

The 3000m steeplechase is an event in which athletes must clear 28 hurdles and 7 water jumps while competing for the fastest time. In this race, women must clear hurdles set at a height of 0.762 meters, whereas men face hurdles set at a height of 0.914 meters. Previous studies have investigated kinematical, and physiological characteristics of the 3000m steeplechase (Earl et al., 2015; Hanley et al., 2020; Hanley & Williams, 2020; Hunter & Bushnell, 2006; Hunter et al., 2008; Kipp et al., 2017). These studies examined the characteristics of the water jump (Hanley et al., 2020; Hunter & Bushnell, 2006; Hunter et al., 2008; Kipp et al., 2017) and pacing strategies (Hanley & Williams, 2020). However, there is a paucity of research on the 3000m steeplechase compared to other long-distance events.

A few studies have reported hurdling non-water jump in the 3000m steeplechase (Earl et al., 2015; Hunter et al., 2006). Earl et al. (2015) investigated the relationship among variables related to hurdling, such as approach velocity, take-off distance, clearance height, and lead knee extension, running economy and running performance. Their findings suggest that there is no correlation between performance in the 3000m steeplechase and the ratio of running economy. Instead, better performance in the 3000m steeplechase might be associated with factors like VO_{2max}, the ability to change pace, and jump technique. Furthermore, Hunter et al. (2006) reported that the length of two steps around hurdles gradually increases. They did not investigate variables around hurdles, such as approach run distance, time, and speed. To the best of our knowledge, no studies have examined variations in per lap variables for hurdling around non-water jumps.

Many middle- and long-distance races often culminate in a sprint competition during the final laps. Previous studies suggested that for mile race, the last lap was either the fastest or the second fastest in 76% of world record races (Noakes et al., 2009). This pace strategy can also be observed in races such as the 5000m and 10,000m (Aragón et al., 2016; Kirby et al., 2021; Tucker et al., 2006). Likewise, an increase in speed during the final lap has been reported in the 3000m steeplechase (Hanley & Williams, 2020). Since hurdles are placed in the home straightaway in the 3000m steeplechase, it is difficult for athletes to maintain acceleration in final sprint. The key to success lies not only in sprinting when athletes are fatigued but also in executing better hurdling. Investigating how to clear the hurdles on the home straight could significantly enhance race strategies and performance.

This study aimed to clarify the characteristics of hurdle clearance for the 3000m steeplechase. The focus was placed on hurdle clearance on the home straight because athletes may experience fatigue after the water jump, leading to differences in performance compared to other hurdles. Various variables related to hurdling around non-water jumps were measured and compared among each lap. If athletes conserve their energy in the second half of the race, they should be able to maintain nearly constant step length, step frequency, and running speed overlaps. It is important for coaches and athletes to understand how to clear the hurdle, because take-off and landing distances for the hurdle could be influenced by fatigue. Athletes could improve their performance in the 3000m steeplechase by acquiring knowledge and skills about hurdling.

METHODS

Participants

Data were collected from the women's 3000m steeplechase races (final) at Kanto intercollegiate race. 15 women's performances were analysed (mean age ± SD = 20.3 ± 1.3 years). The average finishing time (min:s) were 10:51.1 ± 21.5. Informed consent was obtained from participants. This study was approved by the Ethics Committee of the Tokyo Women's College of Physical Education (Kenrinsin 2020-03).

Measures

The 3000m steeplechase races were recorded by video camera (CASIO, EXILIM PRO EX-F1). The sampling rate was 300 Hz and the resolution was 512 × 384 px. The 5th hurdle was placed on home straight. The camera was placed to film the athletes from a sagittal view at 5th hurdle on stadium. The camera was zoomed to include 6 m before and 6 m past the hurdle.

The total time for the 3000m steeplechase races were obtained from results documents (The Inter-University Athletic Union of Kanto). All jumps from participants were digitized using Kinovea (version 0.9.3). Each parameter around hurdle were analysed (Figure 1).

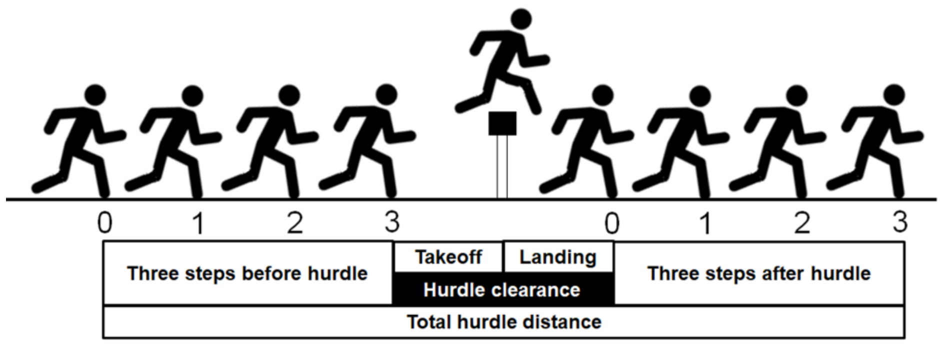

Figure 1. Description for distance of the three steps around hurdle investigated.

Before data collection, I measured 5 m before and 5 m past the hurdle. These measurements were used to create a perspective grid using Kinovea, which made as a reference frame with dimensions of 10 m × 2.5 m. Measures were calculated using Kinovea. We measured the following parameters. Total clearance distance was the horizontal distance from the three steps toe off before hurdle to the three steps toe off after landing. Total clearance time was the total time from the three steps toe off before hurdle to the three steps toe off after landing. Total clearance speed was speed from the three steps toe off before hurdle to the three steps toe off after landing. Take-off distance was the horizontal distance from the take-off toe and front edge of the barrier. Landing distance was the horizontal distance from edge of the barrier to landing toe touching the ground. Clearance distance was the horizontal distance from the take-off toe to landing toe touching the ground. Clearance time was the total time from the take-off toe to landing toe touching the ground. Clearance speed was speed from the take-off toe to landing toe touching the ground.

Distance of three steps before take-off was the horizontal distance from the three steps toe off before hurdle to the take-off. Time of three steps before take-off was the total time from the three steps toe off before hurdle to the take-off. Speed of three steps before take-off was speed from the three steps toe off before hurdle to the take-off toe. Step frequency of three steps before take-off was step frequency from the three steps toe off before hurdle to the take-off toe. Distance of three steps after landing was the horizontal distance from landing toe touching the ground to the three steps toe off after landing. Time of three steps after landing was total time from landing toe touching the ground to the three steps toe off after landing. Speed of three steps after landing was speed from landing toe touching the ground to the three steps toe off after landing. Step frequency of three steps after landing was step frequency from landing toe touching the ground to the three steps toe off after landing. Endpoints of segments were determined by the researchers.

Statistical analysis

Take-off distance, landing distance, clearance distance and clearance time were subjected to one-way ANOVAs with repeated factors of Lap (lap1/lap2/lap3/lap4/lap5/lap6/lap7). Time, length, speed and frequency of three steps around hurdle were subjected to two-way ANOVAs with repeated factors of Lap (lap1/lap2/lap3/lap4/lap5/lap6/lap7) and Around (before/after). Bonferroni correction was applied to post-hoc comparisons. All statistical analyses were conducted using JAPS (0.15.0.0).

RESULTS

Table 1 shows each parameter for the hurdle on the home straight. For total clearance distance, one-way ANOVA revealed that the main effect for lap was significant ($F(6, 84) = 3.41$, $p = .02$, $\eta^2_p = .20$). Post-hoc test revealed that total clearance distance was longer for lap7 than lap4 ($p = .04$). For total clearance time, one-way ANOVA revealed that the main effect for lap was significant ($F(6, 84) = 3.41$, $p = .02$, $\eta^2_p = .20$). Post-hoc test revealed that total clearance time was shorter for lap1 than for lap4 ($p = .01$), lap5 ($p = .01$), lap6 ($p = .01$), and lap7 ($p = .01$). Total clearance time was shorter for lap2 than for lap4 ($p = .03$), lap5 ($p = .02$), and lap6 ($p = .03$). For total clearance speed, one-way ANOVA revealed that the main effect for lap was significant ($F(6, 84) = 3.29$, $p = .03$, $\eta^2_p = .18$). Post-hoc test revealed that total clearance speed was slower for lap4 than lap3 ($p = .05$). Post-hoc test revealed that total clearance speed was higher for lap7 than lap4 ($p = .03$).

Table 1. Parameters from the three steps toe off before hurdle to the three steps toe off after landing. Average (SD).

	Lap1	Lap2	Lap3	Lap4	Lap5	Lap6	Lap7
Total clearance distance (m)	9.87 (0.74)	9.85 (0.98)	10.59 (1.04)	9.83 (1.42)	10.17 (1.06)	9.99 (1.17)	10.74 (0.96)
Total clearance time (s)	2.23 (0.14)	2.29 (0.13)	2.36 (0.10)	2.40 (0.13)	2.41 (0.10)	2.40 (0.10)	2.39 (0.14)
Total clearance speed (m/s)	4.36 (0.24)	4.29 (0.31)	4.48 (0.34)	4.12 (0.69)	4.23 (0.40)	4.17 (0.50)	4.50 (0.45)

Table 2. Parameters for the hurdle clearance. Average (SD).

	Lap1	Lap2	Lap3	Lap4	Lap5	Lap6	Lap7
Take-off distance (m)	0.92 (0.14)	0.93 (0.13)	1.01 (0.14)	0.92 (0.22)	1.01 (0.17)	0.99 (0.16)	1.07 (0.21)
Landing distance (m)	1.29 (0.18)	1.24 (0.26)	1.38 (0.28)	1.28 (0.29)	1.30 (0.28)	1.25 (0.32)	1.31 (0.25)
Clearance distance (m)	2.22 (0.27)	2.22 (0.35)	2.40 (0.35)	2.19 (0.41)	2.30 (0.35)	2.24 (0.36)	2.38 (0.31)
Clearance time (s)	0.53 (0.06)	0.52 (0.07)	0.54 (0.05)	0.55 (0.08)	0.54 (0.06)	0.53 (0.07)	0.53 (0.08)
Clearance speed (m/s)	4.20 (0.60)	4.16 (0.51)	4.46 (0.54)	4.10 (0.90)	4.29 (0.63)	4.26 (0.74)	4.62 (0.88)

Hurdle clearance

Table 2 shows each parameter for the hurdle clearance on the home straight. For take-off distance, a one-way ANOVA revealed that the main effect for lap was significant ($F(6, 84) = 2.82$, $p = .04$, $\eta^2_p = .17$). Post-hoc test revealed that take-off distance was longer for lap7 than lap4 ($p = .04$). For landing distance, a one-way ANOVA revealed that there was no main effect for group ($F(6, 84) = 1.54$, $p = .21$, $\eta^2_p = .10$). For clearance distance, a one-way ANOVA revealed that the main effect for lap was significant ($F(6, 84) = 2.54$, $p = .04$, $\eta^2_p = .15$). Post-hoc test revealed that there was no difference among laps. For clearance time, one-way ANOVA revealed that there was no main effect for group ($F(6, 84) = 0.63$, $p = .60$, $\eta^2_p = .04$). For clearance speed, one-way ANOVA revealed that the main effect for lap was significant ($F(6, 84) = 3.01$, $p = .02$, $\eta^2_p = .18$). Post-hoc test revealed that clearance speed was higher for lap7 than lap4 ($p = .02$).

Comparison for around hurdle clearance

Table 3 shows time, length, speed and frequency of three steps around hurdle clearance. For three steps length around the fifth hurdle, two-way ANOVA revealed that there was a significant interaction between lap and around hurdle ($F(6, 84) = 4.99$, $p = .01$, $\eta^2_p = .26$). Post-hoc tests revealed that three steps length for lap1 was longer after hurdle than before hurdle ($p = .01$). In addition, three steps length before hurdle was longer for lap7 than for lap1 ($p = .01$) and lap2 ($p = .01$) and was longer for lap3 than for lap1 ($p = .01$).

Table 3. Distance, time, speed and step frequency of three steps around hurdle clearance. Average (SD).

	Lap1	Lap2	Lap3	Lap4	Lap5	Lap6	Lap7
Distance of three steps before take-off (m)	3.51 (0.53)	3.60 (0.53)	4.06 (0.59)	3.75 (0.68)	3.86 (0.56)	3.78 (0.60)	4.22 (0.62)
Time of three steps before take-off (s)	0.72 (0.10)	0.74 (0.09)	0.81 (0.10)	0.80 (0.08)	0.81 (0.07)	0.81 (0.07)	0.84 (0.09)
Speed of three steps before take-off (m/s)	4.89 (0.29)	4.85 (0.33)	5.03 (0.34)	4.68 (0.71)	4.76 (0.46)	4.66 (0.54)	5.04 (0.52)
Step frequency of three steps before take-off (Hz)	4.25 (0.50)	4.11 (0.49)	3.78 (0.47)	3.78 (0.37)	3.73 (0.32)	3.74 (0.32)	3.62 (3.67)
Distance of three steps after landing (m)	4.15 (0.30)	4.09 (0.27)	4.14 (0.29)	3.89 (0.51)	4.00 (0.28)	3.97 (0.36)	4.14 (0.35)
Time of three steps after landing (s)	1.02 (0.04)	1.03 (0.03)	1.02 (0.03)	1.05 (0.05)	1.06 (0.04)	1.06 (0.05)	1.03 (0.06)
Speed of three steps after landing (m/s)	4.09 (0.29)	3.97 (0.32)	4.07 (0.29)	3.72 (0.62)	3.80 (0.30)	3.76 (0.41)	4.03 (0.40)
Step frequency of three steps after landing (Hz)	2.96 (0.11)	2.92 (0.09)	2.95 (0.09)	2.86 (0.14)	2.85 (0.09)	2.84 (0.12)	2.92 (0.18)

For time of three steps length around the hurdle, two-way ANOVA revealed there was a significant interaction between lap and around hurdle ($F(6, 84) = 3.58$, $p = .01$, $\eta^2_p = .20$). Post-hoc test revealed that time of three steps before the hurdle was shorter for lap1 than lap3 ($p = .01$), lap4 ($p = .01$), lap5 ($p = .01$), lap6 ($p = .01$), and lap7 ($p = .01$). In addition, time of three steps before the hurdle was shorter for lap2 than lap7 ($p = .01$). Post-hoc test revealed that time of three steps for all laps was shorter before the fifth hurdle than after the fifth hurdle ($ps = .01$).

For speed of three steps around the hurdle, two-way ANOVA revealed the main effect for lap was significant ($F(6, 84) = 3.33$, $p = .03$, $\eta^2_p = .19$). Post-hoc test revealed that speed of three steps tend to be lower lap4 for hurdle than lap3 ($p = .08$) and speed of three steps tend to be lower lap6 for hurdle than lap3 ($p = .09$). Two-way ANOVA also revealed the main effect for around hurdle was significant ($F(1, 14) = 310.25$, $p = .01$, $\eta^2_p = .95$). Post-hoc test revealed that speed of three steps was higher before the fifth hurdle than after the fifth hurdle ($p = .01$). The interaction between lap and around hurdle was not significant ($F(6, 84) = 0.99$, $p = .41$, $\eta^2_p = .07$).

For frequency of three steps around the fifth hurdle, two-way ANOVA revealed that there was a significant interaction between lap and around hurdle ($F(6, 84) = 5.17$, $p = .01$, $\eta^2_p = .27$). Post-hoc test revealed that frequency of three steps length before hurdle was higher for lap1 than for lap3 ($p = .01$), lap4 ($p = .01$), lap5

(p = .01), lap6 (p = .01) and lap7 (p = .01) and was higher for lap2 than for lap3 (p = .01), lap4 (p = .01), lap5 (p = .01), lap6 (p = .01) and lap7 (p = .01). In addition, post-hoc test revealed that frequency of three steps was higher before the fifth hurdle than after the fifth hurdle (p = .01).

DISCUSSION

This study aimed to clarify the characteristics hurdle clearance for the 3000m steeplechase. The performances of 15 female athletes were analysed during an intercollegiate race. I focused on variables of three steps related to the three steps around hurdles, and comparisons were made among each lap. In terms of total clearance speed, we observed that lap4 had a lower speed than lap3, and lap7 had a higher speed than lap4. This finding suggests a decline in speed around the hurdles in the middle of the race, likely due to fatigue. Even when athletes were fatigued, they managed to increase their speed at the last hurdle of the final lap. Similarly, for hurdle clearance, we noticed that the take-off distance in lap7 was longer than in lap4. Furthermore, the clearance speed was higher in lap7 than in lap4. Athletes in the final lap took off from a longer distance and achieved a faster clearance speed. Previous studies have suggested that in many middle- and long-distance races, the final laps often become a sprint competition. For instance, Hanley and Williams (2020) investigated pacing profiles in the 3000m steeplechase and found that 27% of the fastest speeds in a women's race were reached in the final home straight. Additionally, previous study has indicated that the last lap was either the fastest or the second fastest in 76% of world record races (Noakes et al., 2008).

The central governor in the human brain has the ability to predict behaviour to avoid exhaustion and regulate exercise performance (Inzlicht & Marcora, 2016; Noakes et al., 2001; St Clair Gibson & Noakes, 2004; Weir et al., 2006). We observed a statistically significant increase in speed during hurdle clearance in lap7. It is plausible that the "*central governor*" plays a pivotal role in controlling exercise performance, allowing athletes to conserve energy for the final sprint. In this study, the increase in clearance speed can likely be attributed to the final sprint and competition just before the finish line.

Before the increase in speed at the hurdle, there was an increase in the length of three steps in lap7. Our results were almost consistent with those from previous studies (Hunter et al., 2006), which suggested that stride length around hurdles gradually increases throughout the race. In this study, we divided the phases around the hurdle and examined step length, time, speed and frequency. I found that the step length was extended before hurdle clearance, while step length after hurdle clearance did not differ among laps. Additionally, we found that the speed of three steps before the hurdle clearance was higher than the average speed of the entire race, whereas the speed of three steps after the hurdle clearance was lower than the average speed of the entire race. The impact of the landing for hurdle clearance may have applied brakes and caused a decrease in speed. In present study, many athletes were hurdling with their legs placed over the hurdles. In addition, previous studies suggested that women tend to be above the hurdle for a longer time (Hunter et al., 2006). Considering these findings, it is beneficial for female steeplechaser to focus on how to increase their speed after clearing hurdle and landing, as this could lead to performance improvement.

In the present study, we found the interaction lap and around hurdle for step frequency. Specifically, the step frequency before hurdle clearance was higher in lap1 and lap2 than in lap4, lap5, lap6, and lap7. Step frequency after hurdle clearance did not differ among laps and was lower than before hurdle clearance. These findings suggest that the influence of the lap was only evident before hurdle clearance. In the first and second laps, athletes approached the hurdles with a higher step frequency. However, from the third lap onwards, step frequency before hurdle clearance gradually decreased. Fatigue might be a contributing factor to this decline in step frequency before hurdle clearance. Therefore, it would be advantageous for athletes to consciously increase their step frequency when approaching the next hurdle.

Athletes competing in the 3000m steeplechase need to master two hurdling techniques for water jumps and non-water jumps. Although the hurdle height is the same, the required techniques may differ. Emphasizing the pushing motion is essential when jumping from a water pit (Hanley et al., 2020), as fatigue can lead to a shorter landing distance. Moreover, a shorter landing distance for the water jump can make it more difficult for athletes to exit the water pit (Maruo, 2023). Therefore, prioritizing a longer landing distance during hurdle clearance in water jumps can be beneficial. Conversely, in the non-water jumps investigated in this study, increasing step frequency is crucial to maintain speed around the hurdle clearance. Around hurdle clearance, athletes should focus on raising their step frequency to prevent a decrease in speed. Given that there was no main effect for laps on step length, athletes should concentrate on avoiding a reduction in pitch for non-water jumps.

Previous studies have suggested that better performance in the 3000m steeplechase might be associated with factors such as VO_{2max}, strength, the ability to change pace, and jump technique (Earl et al., 2015; Gabrielli et al., 2015; Maruo 2023). Fartlek training could be a valuable method to target changes in step frequency. Fartlek training involves athletes alternating between moderate and high speeds during repeated runs, typically performed in cross-country or forest settings. Considering that our results have shown a statistically significant difference before and after hurdle clearance, training that emphasizes the simple technique of increasing step frequency around hurdle clearance could potentially enhance performance in the 3000m steeplechase.

CONCLUSIONS

In sum, total clearance speed was lower for lap4 than lap3, and was higher lap7 than lap4. This finding suggests a decline in speed around the hurdles in the middle of the race, likely due to fatigue. Before the increase in speed at the hurdle, there was an increase in the length of three steps in lap7. In addition, we found the interaction lap and around hurdle for step frequency. Specifically, the step frequency before hurdle clearance was higher in lap1 and lap2 than in lap4, lap5, lap6, and lap7. After hurdle clearance, step frequency did not differ among laps. Fatigue might be a contributing factor to this decline in step frequency before hurdle clearance. Around hurdle clearance, athletes should focus on raising their step frequency to prevent a decrease in speed. The present study provided practical evidence for hurdle clearance of 3000m steeplechase.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the author.

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