CHAPTER V

DISCUSSION

This study investigated the hurdling performance of Thai male sprint hurdlers with high-level and amateur-level of performance using body kinematics during the hurdle step. In this study, the hypothesis that there exist differences in mean horizontal velocity, takeoff and landing distances, CM parabola path, and body kinematics of trunk and lead leg between high-level and amateur-level hurdlers was explored.

The characteristics of participants

Due to the small sample size, the Mann-Whitney U test was used to compare the differences between the dependent variables between high-level and amateur-level hurdlers. The high-level hurdlers were older, taller, and heavier than the amateur-level hurdlers. Due to limitation of male sprint hurdlers availability, a matched group for age and other anthropometric characteristics can not be formed. However, BMI was not significantly different between groups ($p = 0.083$), which indicated that both groups had similar body type which may have same influence on the control of CM and body mechanics during hurdle step. Additionally, the high-level hurdlers had more experiences and shorter personal best time records than the amateur-level hurdlers. These differences revealed a higher skill of performance for the high-level hurdlers. Therefore, for this study, the height and body mass would not be the causes of any differences in all variables investigated. However, muscles strength and joint range of motion of trunk and lead leg, which might be the important factors that influenced their performance, were not collected in this study.

Mean horizontal velocity

One important requirement for a success in a sprint hurdle race is how fast athletes can get from the start to finish line. Hurdle step is crucial part of the event that greatly influences the race time. The mean horizontal velocity of hurdle step is the variable that has been widely used to determine athlete's performance (3, 4, 5, 7). For this study, the high-level hurdlers were able to cross the hurdle significantly faster than the amateur-level hurdlers. Mean horizontal velocity ranged from 7.21 m/s to 8.23 m/s for the high-level hurdlers and 6.06 m/s to 6.90 m/s for the amateur-level hurdlers (Table D1). The values indicated that both groups of Thai athletes performed with less values of mean horizontal velocity compared with the previous study. McDonald et al. (5) reported horizontal velocity of 8.57 m/s for the Olympic level hurdlers.

Although, the athletes in this study did not perform the actual race with ten hurdles as the competition, data from their previous races were available from the questionnaire. The high-level hurdlers had their best time records ranged from 13.92 s to 15.20 s whereas the amateur-level hurdlers' records were 20.24 s to 24.50 s. The results are in agreement with their previous records which showed that the high-level hurdlers were faster, therefore had shorter time for the competition.

The mean horizontal velocity is associated with step length and flight time. If the athlete has less value of flight time and longer step length of hurdle step, he will cross the hurdle faster during hurdle step. Table D1 shows that the high-level hurdlers spent less time than the amateur-level hurdlers, resulted in greater mean horizontal velocity during hurdle step.

The mean horizontal velocity depends on the initial horizontal velocity during takeoff. The extensor muscles strength of trail leg might be a crucial part that influenced horizontal velocity during takeoff as it generated forward angular momentum in the early part of the hurdle step (14). The more values of forward angular momentum of the trail leg resulted in faster movement of the body during takeoff phase. From the results, it may be indicated that the amateur-level hurdlers might had less extensor muscles strength of trail leg. Additionally, the vertical forces exerted against the ground as the ankle was plantarfexed was increased, which lead to the gain in vertical velocity during takeoff (18).

Furthermore, the concentric and eccentric-concentric mechanism of six muscles of trial leg might be associated with the trail leg posture during takeoff (18). During takeoff, gluteus maximus, hamstrings, and rectus femoris muscles worked together in order to control the trail hip position in extension angle, and the vasti, soleous and gastrocnemius of trail leg generated knee extension and plantarflexion angles of trail leg. At the instant of touchdown to takeoff, gluteus maximus remained at a near constant length for the first part of the takeoff and then shortened, hamstrings shortened throughout the takeoff, rectus femoris lengthened throughout the takeoff, and the vasti, soleous and gastrocnemius experienced the lengthening-shortening sequence of actions. As the mechanism of trail leg muscles during takeoff phase, stretching and strength training might be the appropriated training program, and the plyometric exercise is beneficial training exercise because it can develop the athlete’s ability to benefit from the stretch-shortening cycle. Thus, plyometric exercise training of trail leg muscles should be included in the amateur-level hurdlers' training program.

Take-off and landing distances

For this study, takeoff and landing distances were not statistically significant differences between the hurdlers with different level of performance (Figure 5). The distances for both groups were similar to the distances recommended by professional hurdling coaches. In addition, the subjects in this study performed with similar takeoff and landing distances as compared to previous studies, 2.25 ± 0.25 m and 1.44 ± 0.35 m, according to Finch et al. (3); 2.12 ± 0.14 m and 1.50 ± 0.15 m, according to McDonald et al. (5); 2.15 ± 0.14 m and 1.49 ± 0.14 m, according to Salo et al. (4).

Although, the high-level hurdlers had longer leg length which may give them an advantage over the amateur-level hurdlers to be able to takeoff farther away before approaching the hurdle, this was not found to be the case since takeoff and landing distances normalized to leg length were not statically significant differences between groups. This result is suggested that leg length did not influence takeoff and landing distances. The regularity of interhurdle running and the confident of the hurdlers to approach the hurdle might be the important factors that influence the takeoff distance (6). The fast running velocity associated with proper running posture while approaching the hurdle facilitates the optimal distance and more initial velocity during takeoff.

Center of mass parabola path

For the CM parabola path, three variables were used to explain the vertical displacement and horizontal displacement of CM during passing over the hurdle. The dependent variables of clearance height and CM lift were determined as the CM vertical displacement. From the results, there was no statistically significant difference for clearance height between skill level groups. Besides, the amateur-level hurdlers had greater CM lift than the high-level hurdlers, which suggested that the amateur-level hurdlers had to raise their CM higher than the high-level hurdlers to safety cross the hurdle of the same height. Although, the amateur-level hurdlers were significantly shorter in height, the differences in their CM lift still exists when normalized to their leg length values (33.87 % to 41.47 % for high-level and 17.77 % to 24.21 % for amateur-level, $p = 0.021$). In addition, when compared to the previous studies investigating the Olympics level hurdlers, the hurdlers in both groups had greater CM lift than the values reported by Finch et al. (3) (0.15 ± 0.07 m) and Salo et al. (4) (0.30 ± 0.05 m). Salo et al. (7) had described that when the hurdlers had to raise their CM from lower position over the hurdle in a shorter distance, it would result in more vertical lift which consequently affected the energy wastefulness during crossing over the hurdle.

The dependent variable for the horizontal displacement of peak of CM parabola path to the hurdle was determined as the CM horizontal displacement. The longer takeoff distance allowed the hurdlers more distance to approach the hurdle horizontally, and attained the highest point of CM parabola path in front of the hurdle (4, 5). There was no statistically significant difference for horizontal displacement of peak of CM parabola path to the hurdle between the two groups (Table D2).

However, when the horizontal displacement of peak of CM parabola path was expressed in relation to the takeoff point (% distance from take-off spot), the high-level hurdlers had greater % distance to raise the lead leg over the hurdle, and was able to reach the highest point of CM parabola path at farther % distance from the takeoff point than the amateur-level hurdlers (41.90 % to 56.58 % for high-level and 36.98 % to 41.23 % for amateur-level, p = 0.021). In comparison with the previous research, the athletes in this study performed with greater horizontal displacement of peak of CM parabola path to the hurdle (0.14 m to 0.69 m for high-level and 0.58 m to 0.70 m for amateur-level) than the values reported by Finch et al. (3) (0.03 ± 0.32 m) and McDonald et al. (5) (0.03 ± 0.15 m). However, a direct comparison with the previous studies should be done with care because different methods and definition of CM were used.

The less values of CM lift and clearance height in addition to having the highest point of CM parabola path in front of the hurdle represented the lower shape of CM parabola path during hurdle step (4). The lower shape of CM parabola path was considerable the appropriate margin of CM trajectory while crossing over the hurdle because it required less CM vertical displacement and longer CM horizontal displacement. The less CM vertical displacement required a smaller change in vertical velocity during takeoff, which reduced the loss of horizontal velocity, and thus resulted in more mean horizontal velocity (4). Similar to projectile motion, the vertical displacement of CM parabola path depends on the initial vertical velocity at takeoff and gravity force (19). In early part of the hurdle step, an increasing in vertical velocity and positive gravity forces result in body elevation. In final part of the hurdle step, the negative gravity forces lead to fast downward motion of the body to the ground. The horizontal displacement of CM parabola path depends only on the initial horizontal velocity during takeoff which remains constant until landing to the ground.

The differences in CM parabola path between the two skill level groups may be attributed to the higher force production of leg extensor muscles (5). The extensor muscles helped to resist flexion of leg joints and allowed the hurdlers to approach the hurdle with lower CM parabola path (4). Besides, the angular momentum of the trail leg during takeoff was found to be an important factor in the distribution of the forward rotation component of the angular momentum of the body, resulting in elevation of the body in the early part of hurdle step (14).

One additional variable that can be used to determine CM parabola path is the CM height at takeoff and landing. The higher CM height at takeoff and landing characterized the lower CM parabola path during hurdle step (4). Figure 6a illustrates a lower CM parabola path of the high-level hurdlers as they took off and landed with higher CM height than the amateur-level hurdlers ($p = 0.021$ and 0.020, respectively). The CM height at takeoff ranged from 1.00 m to 1.13 m for the high-level hurdlers and 1.08 m to 1.13 m for the amateur-level hurdlers. The CM height at landing ranged from 0.92 m to 0.98 m for the high-level hurdlers and 0.90 m to 0.94 m for the amateur-level hurdlers.

Angular displacement of trunk and lead leg

The results indicated that there were no statistically significant group differences for maximal trunk flexion, maximal hip flexion, and maximal knee extension. The standard hurdle's height (1.067 m) was used in this study, allowed both high-level and amateur-level hurdlers to face similar demand on movements of the trunk and lead leg during the hurdle step. The hurdle step can be divided into three sub-phases (takeoff, clearance, and landing). Therefore, for clarification of the analysis, angular displacements of the trunk and lead leg will be discussed according to the separated phases of the hurdle step.

Sub-phase: Take-off

Generally, during takeoff phase, the trunk is in a slightly forward position, and the shoulders are slightly ahead of the hips. In comparison with the high-level hurdlers, the amateur-level hurdlers took off with less trunk flexion angle (22.7° to 36.2° for high-level and 18.9° to 24.6° for amateur-level, $p = 0.043$). Professional coach (2) suggested that during takeoff, having the trunk in flexion might help the hurdlers to minimize the CM lift. However, there had no kinematics information for trunk and lower extremities angles specifically during takeoff, thus it can not inform the exact values of the trunk angle during takeoff. Considering that the amateur-level hurdlers took off with less trunk flexion, it might cause the ineffective hurdle clearance such as more CM lift, greater flight time.

Furthermore, the leaning of trunk and arms swinging were considerably in the opposite direction of the lifting of lead leg. McDonald et al. (14) found that angular momentum of the head-trunk and the arms were approximately equal and opposite to the angular momentum of the lead leg. Thus, the angular momentum of the trail leg played an important role in body progression during takeoff phase.

Sub-phase: Clearance

McDonald et al (5) suggested that during the clearance phase, the trunk needs to be leaned more forward together with hip flexion in order to keep CM closer to hurdle and the knee is extended to prepare for landing. From Figure 10b, there was only one amateur-level hurdler performed with less trunk flexion. Similar trend of hip flexion angle were demonstrated for both groups after the hip reached maximal flexion angle during hurdle clearance (Figures 11a and 11b). However, the high-level hurdlers were able to maintain the hip maximal joint angle more smoothly than the amateur-level hurdlers. This implied that the high-level hurdlers were more capable of maintaining the hip position throughout the clearance phase. As the movement involves multi-joint control, the ability to control movement of the hip was also reflected at the knee joint. From Figure 12b, the amateur-level hurdlers awkwardly controlled knee extension during hurdle clearance as indicated by the more wavy profile of the knee angle displacement compared to that of the high-level hurdlers.

Considering motions of the lead leg, the transferred momentum of thigh when the hip was flexed produced extension at knee joint (14). This was because rectus femoris and hamstring muscles are two-joint muscles, which cross over the hip and the knee, and a characteristic of these muscles did not permit complete movement in both joints simultaneously.

Sub-phase: Landing

Professional coaches suggested during landing phase, the trunk should be in a slightly forward position (trunk flexion) and the shoulders are slightly ahead of the hips, the hip is in a “hips tall position” (straighten joint angles), and the knee is fully extended (12). To land safely with proper mechanics, the trunk needs to be in an optimal position. The excessive trunk flexion caused the lead foot to sink into the ground, resulted in imbalance during landing. Landing with less trunk flexion caused improper mechanics during landing such as heel contact instead of forefoot contact, and knee flexion which made it difficult to push backward on the ground to initiate the next interhurdle step, and finally lost of horizontal velocity during interhurdle steps (20).

The downward motion of the lead leg was produced mainly by transferred of angular momentum from the trail leg (14). The large amount of forward angular momentum of trail leg at takeoff and proper landing position helped to generate a fast landing of the body.

Temporal variables

For the flight time during hurdle step, it took shorter time for the high-level hurdlers to go from the takeoff to landing compared to the amateur-level hurdlers. This influenced temporal variables of trunk, hip, and knee angles. The high-level hurdlers had shorter time to reach maximal hip flexion and maximal knee extension than the amateur-level hurdlers (Table D3). For the time to maximal trunk flexion, the p-value approach statistically significant difference (0.17 s to 0.20 s for high-level and 0.19 s to 0.35 s for amateur-level, $p = 0.080$). This may be due to the different of muscle power of hip flexor muscles and knee extensor muscles, which can be determined from muscle strength and time spending for the movement. Although, muscle strength was not examined in this study, the less in the values of time to reach maximal hip flexion and knee extension of the high-level hurdlers revealed the higher muscle power of the high-level hurdlers. It can be indicated that the high-level hurdlers can perform quicker movement of the body during hurdle step than the amateur-level hurdlers.

In summary, from the results of trunk and lead leg angles, the amateur-level hurdlers had a tendency to perform similar techniques relative to the high-level hurdlers. In other words, the amateur-level hurdlers have a potential to be able perform more closely to the high-level hurdlers if they are further coached and well-trained. Considering their current ability, several factors prohibited the amateur-level hurdlers to compete with the high-level hurdlers. Most notable factor is an inability to produce optimal horizontal velocity during hurdle step. The amateur-level hurdlers crossed the hurdle slower than the high-level hurdles. Additionally, their vertical displacement of CM during crossing the hurdle was still greater than that of the high-level hurdlers, which consequently caused the longer time to reach maximal angle of the lead leg angles.

CONCLUSION

This study investigated the kinematics characteristics used by Thai hurdle athletes with higher skill level in comparison to those with lower skill athletes. It was found that different movement techniques were used during hurdle step. Based on the results, the high-level hurdlers crossed the hurdle faster and raised CM from the takeoff point to the peak of CM parabola path less than the amateur-level hurdlers. The differences between groups are mainly related to individual techniques and leg muscles strength. However, according to the characteristics of trunk and lead leg angles, there were tendencies for the lower skilled hurdlers to perform similar techniques relative to the higher skilled hurdlers.

FUTURE STUDY

Future studies with larger sample size and integrated kinematics, kinetics, and electromyography are needed to confirm results of this study and extend for further knowledge. Other participant's characteristics, such as muscle power and flexibility of trunk and lower extremities muscles should be examined and included in the analysis. Additional kinematic data of trail leg angles at takeoff would be helpful in quantifying propulsion of the body for hurdle clearance. Electromyography of gastrocnemius muscles of trail leg and hip flexors and knee extensors of lead leg can be used to determine how much and how fast the forces are generated during hurdle clearance. Video records of frontal plane of movements can help to determine if arm swing and trail leg movements effect trunk and lead leg movements. Additionally, kinematic analysis of three consecutive steps prior to the hurdle step can help to determine ability to maintain performance throughout the race. Future studies are also needed to be carried out in both competition and training situations since competition situation obtain better performance but unable to carry out desirable measurement setup as in training situation.