Original Article

Recommendations for instructional content: relationship of hurdle clearance motion with body height and hurdle running time in 12-14 year old boys

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Abstract:
This study aimed to clarify the relationships between body height, hurdle clearance motions, and 50m hurdle running times in 1st and 2nd grade junior high school students, aged 12 to 14. Eighteen Japanese junior high school boys participated in the study. The 50m hurdle running times were measured at the 5.5m, 6.0m, and 6.5m inter-hurdle distances, with hurdle heights set at 0.68 m and using randomized trial orders. The clearance motion on the second hurdle was captured by a motion capture system sampled at 250 Hz. Maximum hurdling heights (vertical distance between distal point of pelvis at the maximum jumping height during hurdle clearance and ground) were 1.14 ± 0.06 m, 1.13 ± 0.05 m, and 1.12 ± 0.05 m at 5.5m, 6.0m, and 6.5m inter-hurdle distances, respectively. The following results were obtained for all inter-hurdle distances. No significant relationship was found between the hurdle running times and the maximum hurdling heights. These maximum hurdling heights did not relate to the vertical hurdling displacements, and significantly related to the body height (5.5 m: r = −0.477; 6.0m: r = −0.562; 6.5m: r = −0.559). This suggests that boys should not be instructed to clear hurdles as low to the hurdle as possible and that smaller up-and-down movements should be carefully taught based on the boys’ physical characteristics. Even when the faster boys exhibited smaller vertical hurdling displacements, their times were significantly related to the longer horizontal hurdling distances (5.5 m: r = −0.547; 6.0m: r = −0.683; 6.5m: r = −0.771), not maximal hurdling heights nor body height. Therefore, it may be possible to develop the ability to jump as long as possible and sprint in turn through the physical education hurdle class, while improving the boys’ running time.

Key words: instructional content, motion capture system, maximum hurdling height, correlation coefficients.

Introduction
Hurdle running requires coordinating multiple sprint running and jumping movements. In Japan’s Course of Study, the ability to clear hurdles smoothly from rhythmical running during a race is highlighted as a physical education (PE) motor-skill objective for junior high school 1st-2nd grade students (12-14 years old; the relationship between developmental stage and age range in Japan is shown in Table 1) (Ministry of Education, Culture, Sports, Science, and Technology in Japan, 2008a). This leads us to understand that the teaching of this motor skill requires the student to run inter-hurdle distances using a rhythm-closing sprint running motion and to minimize deceleration of the entire-body center of mass (COM) anteriorly during the hurdle clearance motion rather than to jump over hurdles.

Table 1. Extracted developmental stage, grade, and age range in Japanese school system

<table>
<thead>
<tr>
<th>Developmental stage</th>
<th>Grade</th>
<th>Age range (year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elementary school</td>
<td>5</td>
<td>10-11</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>11-12#</td>
</tr>
<tr>
<td>Junior high school</td>
<td>1</td>
<td>12-13#</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>13-14</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>14-15</td>
</tr>
<tr>
<td>High school</td>
<td>1</td>
<td>15-16</td>
</tr>
</tbody>
</table>

# Peak height velocity in Japanese boys occurs at this stage.

Recently, sports biomechanical studies have examined students’ motions in hurdle running classes and have reconsidered motor skills content instruction in PE. With particular attention paid to the hurdle clearance motion, most of these studies have suggested that the ability to start from a further position toward a hurdle related to a shorter hurdle running time (Yasui et al., 1996) and the ability to run inter-hurdle distances using a
three-step rhythm (Fujita et al., 2009). Interestingly, previous studies on 6th grade elementary school students (aged 11-12 years old) revealed that the ability to land at a position further from a hurdle related to shorter hurdle running time as well as the ability to take off from a further position toward a hurdle (Ito, 2009; Otsuka et al. 2010). This result did not validate the conventional motor skill instruction content found in PE instructional textbooks, which is to land at the nearer position from a hurdle (Doi, 2000; Dibiki, 2003; Shimizu, 2008). In addition, the motor skills needed to jump anteriorly are emphasized in the hurdle clearance motion, and can be regarded as a different motor skills of closing in the sprinting motion indicated as a Course of Study objective in Japan (2008a).

In contrast to fixed inter-hurdle distance (male: 9.14m; female: 8.50 m) cited in athletic regulations for adult athletes (International Association of Athletics Federations, 2014), in PE, various inter-hurdle distances are prepared by the PE teacher (Nomi, 2001). With an optimal inter-hurdle distance in which each student is able to run his or her fastest, larger horizontal distances from the starting position to landing position in the hurdle clearance motion (hereafter, horizontal hurdling distance) contribute to shorter hurdle running records (Ito, 2009; Otsuka et al., 2010). However, in some educational contexts, there are fewer hurdles due to limited budgets and/or limited track size; therefore, not every student can select and run in their own optimal inter-hurdle distance. The current Course of Study and related guidelines do not list the motor skills for hurdle clearance based on difference in inter-hurdle distances (Ministry of Education, Culture, Sports, Science and Technology in Japan, 2008a, 2008b). Therefore, in PE, it is important to clarify the relationship between hurdle running times and hurdle clearance motions for various inter-hurdle distances.

In the coaching field, the motor skill needed to take off from a further position toward a hurdle and clear the hurdle as low to the hurdle as possible is an achievable goal for adult athletes (Arnold, 1993; Hay, 1978), and elementary and junior high school students (Gavin, 1977). Therefore, this hurdle clearing motor skill is also taught from the developmental stage in elementary school PE (Hosoe, 2006; Dibiki, 2003; Nomi, 2001; Shimizu, 2008). The hurdle running time is not associated with the hurdle clearance time from take-off to landing, which is equal to vertical displacement during the hurdle clearance motion (hereafter, vertical hurdling displacement) (Ito, 2009; Otsuka et al., 2010). However, this vertical displacement does not directly indicate the vertical distance between the hurdle and the student’s body (e.g. distal point of pelvis) when evaluating the ability to clear as low to the hurdle as possible. Therefore, further biomechanical investigation is needed.

It has been noted that vertical hurdling displacement is associated with body height in the coaching field (Arnold, 1993; Forman, 1972; Gathrie, 2003; Gravin, 1977; Hay, 1978; MacFarlane, 1993; White, 1980). Arnold (1993) cited that taller hurdlers could take off toward a hurdle at higher body position. This effect of body height to hurdle clearance motion would be witnessed in PE. Peak height velocity in Japanese boys occurs between 12-13 years old (Ministry of Education, Culture, Sports, Science and Technology in Japan, 2014), and this timing shifts before and after based on the individuals (Tanner, 1962). In Japan, 13-year-old boys who have matured early are taller than other boys (Fukunaga et al., 2013). This suggests that in PE classes for junior high school 1st and 2nd grades, there may be a wide range of body heights between various boys. Therefore, it is important to clarify not only the relationship between the hurdle running times and hurdle clearance motions, but also the relationship between body height and hurdle clearance motions when developing instructional content and materials for junior high hurdle running classes for 1st and 2nd grade boys (aged 12-14 years old), who are at the age in which peak height velocity occurs.

The purpose of this study was to determine relationships among body height, hurdle clearance motions, and hurdle running times for various inter-hurdle distances measured for 1st and 2nd grade boys in junior high school, and to provide information useful to developing hurdle running class instructional content.

Method
Participants
The participants included eighteen boys in 1st and 2nd grade in junior high school (age: 13.5 ± 0.6 year, mean ± standard deviation; body height: 157 ± 11 cm; body mass: 43 ± 8 kg; body mass index: 17.2 ± 1.3kg/m²). The purpose and details of the data collection process were explained to the participants and their guardians before the experiment, and informed consent was obtained. This experiment was conducted after obtaining approval from the blinded Research Ethics Committee.

Experimental trial
A total of three 50-m hurdle running trials, which were set at inter-hurdle distances of 5.5, 6.0 and 6.5m, respectively, were conducted in random order. All participants ran alone using a three-step rhythm during the trials. The distance from start to first hurdle was set at 12.0 m so that all participants were able to run with eight steps. In PE class, due to the limited number of hurdles and other issues, hurdle running is often conducted using same hurdle height (Dibiki, 2003; Ito, 1985; Shimizu, 2008). Therefore, for each hurdle running trial, five hurdle heights were set at 0.68 cm, which is the height normally used in PE classes for junior high school boys (Nomi, 2001). This hurdle height was 43% of the mean value of the participants’ body heights and was less than 45% of that of the subischial leg lengths (Hashizume, 1983). These hurdle running trials were conducted on an indoor single-lane experimental course in order to remove the effect of wing speed on hurdle running motion. Before

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this experimental trial, the participants were provided with two separate introduction lessons on hurdle running, the objectives of which were for participants to determine their own leading and trailing legs and to learn how to land with the other leading leg. In these introduction lessons, all participants were able to run the inter-hurdle distance at 6.5 m. Therefore, the 6.5-m inter-hurdle distance was set as the longest inter-hurdle distance in experimental trial.

Before the hurdle running trials, a 50-m sprinting time was recorded.

Data collection and analysis

The hurdle running times and sprinting times were calculated using a video camera (HDR-CX170; Sony; Japan), which was placed at left side of the goal line and sampled at 60 Hz. The times were recorded from when the gun flashed until the participant’s torso passed the goal line.

During hurdle running trials, reflective markers (12 mm diameter spheres) were attached to participant’s surface on the anterior superior iliac spines (ASISs), posterior superior iliac spines (PSISs), first metatarsal heads, and fifth metatarsal heads on the right and left sides. Hurdle clearance motion from take-off to landing at the second hurdle was captured using a 15-camera motion capture system (Raptor-E digital; Motion Analysis Corporation, Santa Rosa, CA) sampled at 250 Hz.

The 8 marker trajectories data for each participant was filtered using a fourth-order, zero-lag low-pass Butterworth filter with a cut-off frequency of 10 Hz. Three-dimensional displacements of reflective markers for ASISs and PSISs were used to estimate the distal point of the pelvis segment using an anatomical prediction approach (Reynolds, 1982). The following hurdle clearance motion parameters were analyzed (Figure 1):

1) Maximum hurdling height: The peak value of the vertical distance between the distal point of the pelvis segment and the ground during the hurdle clearance motion.
2) Horizontal hurdling distance: The horizontal distance between the midpoint of the first and fifth metatarsal heads at the take-off instant and the midpoint of the first and fifth metatarsal heads at the landing instant.
3) Vertical hurdling displacement: The vertical distance between the distal point of the pelvis segment at static pause and maximum hurdling height.

Here, we focused on parameters that PE instructors can easily understand.

Statistical analysis

All parameters were presented as mean ± standard deviation. Repeated analysis of variance was used to compare variables in the 5.5-, 6.0- and 6.5-m inter-hurdle distances. Bonferroni’s test for multiple comparisons was performed when statistical significance was noted. Pearson's correlation coefficients were used to identify relationships among variables. A p value < 0.05 indicated statistical significance.

Results

The 50-m hurdle running times in the 6.0-m and 6.5-m inter-hurdle distances were shorter than that of the 5.5-m inter-hurdle distance (Table 2). The 50-m sprinting time was 8.24 ± 0.61 s.

For all inter-hurdle distances, significant negative relationships were noted between the 50-m hurdle running times and body height (fig. 2), while significant positive relationships were noted between the 50-m hurdle running times and the 50-m sprinting time.

Table 2. Differences in hurdle running time and hurdle clearance parameters (mean ± SD)
For all inter-hurdle distances, no significant relationships were noted between the 50-m hurdle running times and the maximum hurdling heights (fig. 3). In contrast, for all inter-hurdle distances, significant negative relationships were noted between the 50-m hurdle running times and the horizontal hurdling distances.

Fig. 3. Relationships of the 50-m hurdle running times between the maximum hurdling heights (panel A) and horizontal hurdling distances at 5.5-, 6.0-, and 6.5-m inter-hurdle distances (panel B). Black dashed lines show the hurdle height (0.68 m). Gray solid lines show the mean values of maximum hurdling height at each inter-hurdle distance. *: P < 0.05; **: P < 0.01; n.s.: no significance.

For all inter-hurdle distances, no significant relationships were noted between the vertical hurdling displacements and the maximum hurdling heights (fig. 4). In contrast, positive significant relationships were noted between the vertical hurdling displacements and the body height.
Fig 4. Relationships of the vertical hurdling displacements between the maximum hurdling heights (panel A) and body height at 5.5M, 6.0M, and 6.5M inter-hurdle distances (panel B). Black dashed lines show the hurdle height (0.68 m). *: P < 0.05; n.s.: no significance.

For all inter-hurdle distances, horizontal hurdling distances were not significantly correlated with maximum hurdling heights and body height (fig 5).

Fig. 5. Relationships of the horizontal hurdling distances between the maximum hurdling heights (panel A) and body height at 5.5M, 6.0M, and 6.5M inter-hurdle distances (panel B). Black dashed lines show the hurdle height (0.68 m). n.s.: no significance.

Discussion

**Recommendations for Instructional content for hurdle clearance motion**

In all inter-hurdle distances, the boys who had shorter 50M hurdle running times had greater body height (Figure 2-A) and shorter 50M sprinting times (Figure 2-B). The 13 year-old boys who matured early were taller than the other boys (Fukunaga et al., 2013). This suggests that the boys who were faster in hurdle running were not only taller, but early matured body whose physical fitness is high (Fukunaga et al., 2013; Kato et al., 1999; Otsuka et al., 2010; Tanner, 1962). Therefore, in junior high school PE, the hurdle running unit may involve a level of uncertainty, as to winners are possibly determined even before the race.

No significant relationships were noted between the 50M hurdle running times and the maximum hurdling heights in all inter-hurdles distances (Figure 3-A). The maximum hurdling heights in each 5.5-, 6.0- and 6.5-m inter-hurdle distance were 1.14 ± 0.06 m, 1.13 ± 0.05m, and 1.12 ± 0.05 m, respectively. In this study, the hurdle height was 0.68 cm; therefore, most of participants were jumping over the hurdle at 0.44 to 0.46 m above. Previous studies on hurdle running with adult athletes have reported that the vertical displacement between the hurdle and the COM was 0.28 to 0.35 m for men (Coh, 2004; Mero & Luhtanen, 1991; McDonald & Dapena, 1991) and 0.35 m for women (McDonald & Dapena, 1991). When clearing the hurdle, the COM continues to be
above the distal point of pelvis. These mean that, compared to an adult athletic hurdler, most of participants jumped over the hurdle at safe vertical distances. This does not support the conventional motor skill instructional content found in some instructor manuals (Nomi, 2001).

This maximum hurdling heights did not correlate with the vertical hurdle displacement in all inter-hurdle distances (Figure 4-A). This may indicate that reducing vertical displacement while clearing the hurdle does not result in clearing the hurdle as low to the hurdle as possible. In this study, maximum hurdling heights correlated with body height (Figure 4-B). This suggests that even if the taller boys reduce their vertical displacement, they do not clear hurdle at close to the hurdle height. In other words, shorter boys may be not able to clear the hurdle without enough vertical hurdling displacement. Therefore, the instructional content related to clearing the hurdle as low to the hurdle as possible is not necessary for the PE hurdle unit. Instructional content on hurdle clearance height should be developed such that it accounts for each student’s individual height.

In sprint running, if the aerial time from the take-off instant to the next landing is short and the vertical displacement of the COM is small, the horizontal displacement of the COM is also small during the aerial phase (Hunter et al., 2004). Nonetheless, in all inter-hurdle distances, the boys who were faster in hurdle running and whose maximum hurdling heights was larger had greater horizontal hurdling distances (Figure 3-B). This suggest that even if boys who are fast in hurdle running reduce their vertical displacement when clearing the hurdle, they will still be unable to land at a further position without utilizing a higher horizontal velocity of COM at the immediately preceding take-off. Furthermore, no significant relationships were noted between horizontal hurdling distances and maximum hurdling heights in all inter-hurdle distances (Figure 5-A). This may lead us to understand that clearing hurdles closer to the hurdle height is not related to long horizontal hurdling distance, and thus does not support the instructional content taught in junior high school PE classes (Nomi, 2001). Finally, it was suggested that the body height of boys does not contribute to horizontal hurdling distance in all inter-hurdle distances (Figure 5-B). From these findings, we concluded that the motor skills needed to jump over hurdles anteriorly, which can involve jumping highly, can be included in the instructional content for fast hurdle running in the junior high PE hurdle unit.

**Effect of different inter-hurdle distances on instructional content**

In the PE hurdle running unit, PE teachers often include a variety of inter-hurdle distances, and encourage boys to select one of them based on the individual boy’s ability (Nomi, 2001). Figure 6 illustrates the relationships between maximum hurdling height and horizontal hurdling distance in the 50-m hurdle running time to determine each boy’s optimal distance for fastest running between the three inter-hurdle distances. As a result, we found that there was no significant relationship between hurdle running time and maximum hurdling height in the optimal inter-hurdle distance. In contrast, hurdle running time significantly correlated with horizontal hurdling distance in the optimal inter-hurdle distance. In addition, the relationships between body height, hurdle clearance motion, and hurdle running time did not change based on different inter-hurdle distances. Therefore, the differences in inter-hurdle distance may not affect the relationships between body height, hurdle running motion, and hurdle running time. This suggests that it is not necessary to change the instructional content on hurdle clearance motion based on different inter-hurdle distances.

**Fig. 6.** Relationships of the 50-m hurdle running record between the maximum hurdling height (panel A) and hurdling distance at an optimal inter-hurdle distance (panel B). ●, ▲, and × show students whose hurdle running record were shortest at 5.5-, 6.0-, and 6.5-m inter-hurdle distances, respectively. Black dashed lines show the hurdle height (0.68 m). **: P < 0.01; n.s.: no significance.
In 5.5-m inter-hurdle distance, the relative value of horizontal hurdling distance to inter-hurdle distance was 39.4% (calculated based on Table 1), and was over 38.1% of that in 6.0-m and 36.6% of that in the 6.5-m inter-hurdle distances. The boys who were faster in hurdle running had greater horizontal hurdling times not only in the 6.0-m and 6.5-m inter-hurdle distances, but also in the 5.5-m inter-hurdle distance. If the horizontal hurdling distance in the short 5.5-m inter-hurdle distance is lengthened, the boys may have to shorten the step length of a three-step rhythm and enhance their step rate to run fast. This should be considered when developing PE instructional content for inter-hurdle running.

Conclusion

From these findings, we concluded that developing the motor skill necessary for jumping over hurdles anteriorly, which can involve jumping high, can be included in the instructional content for fast hurdle running in the junior high school PE hurdle unit. The learning objective in developing this motor skill in junior high school boys is similar to that for elementary school students, which is “acquiring a motor skill of jumping over the hurdle as high and far as possible without decelerating anteriorly, balancing the whole-body during aerial phase, landing, and re-sprinting repeatedly” (Ito, 2010; Otsuka et al., 2011). This objective is emphasized in order to associate different developmental stages in schools and to organize and systematize the PE instructional content in Japan (Ministry of Education, Culture, Sports, Science and Technology in Japan, 2008a, 2008b). According to Ito (2010)’s systematization of instructional content for junior high PE hurdle running, which follows the elementary school stage in which students experience jumping as long and high as possible, boys should be taught to parallel the trailing leg to the trunk and lean the trunk forward (as a result, the trailing leg parallel to the ground) in order to clear higher hurdle heights and develop the motor skills needed for hurdle clearance motion. Most of men’s top-level adult hurdlers clear hurdles of which the height (1.07 m) is 59% relative to body height (mean value: 1.81 m) (Karube, 2013). This suggests that the men’s top-level adult hurdlers clear a higher hurdle; in contrast, junior high school boys clear a lower hurdle (43% of body height [mean value: 1.58 m]). In addition, the horizontal hurdling distance of the men’s top-level hurdlers is 3.59 to 3.96 m (Coh, 2004; Fortune, 1998; McDonald & Dapena, 1991; Ito, 2010; Salo et al., 1997), suggesting that they are jumping over the hurdle anteriorly rather than stepping over the hurdle. Therefore, it is valuable to develop the motor skills needed to jump over hurdles as long and high as possible and shorten the hurdle running time at the junior high school stage.

References


