Journal of Physical Education and Sport ® (JPES), 15(2), Art 30, pp. 194 - 201, 2015
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

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

MITSUO OTSUKA[1], SATOSHI OTOMO[1], TADAO ISAKA[1], TOSHIYUKI KURIHARA[1], AKIRA ITO[2]
[1]Faculty of Sport and Health Science, Ritsumeikan University, JAPAN
[2]Faculty of Health and Sport Sciences, Osaka University of Health and Sports Science, JAPAN

Published online: June 26,2015
(Accepted for publication April 20, 2015)
DOI:10.7752/jpes.2015.02030;

Abstract:
This study aimed to clarify the relationships between body height, hurdle clearance motions, and 50-m 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 50-m hurdle running times were measured at the 5.5-m, 6.0-m, and 6.5-m 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 5.5-m, 6.0-m, and 6.5-m 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

Developmental stage	Grade	Age range (year)
Elementary school	5	10-11
	6	11-12#
Junior high school	1	12-13#
	2	13-14
	3	14-15
High school	1	15-16

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

Corresponding Author: MITSUO OTSUKA, E-mail: otsuka-a@st.ritsumei.ac.jp

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 Couse 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/m^2). 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 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 splines (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):

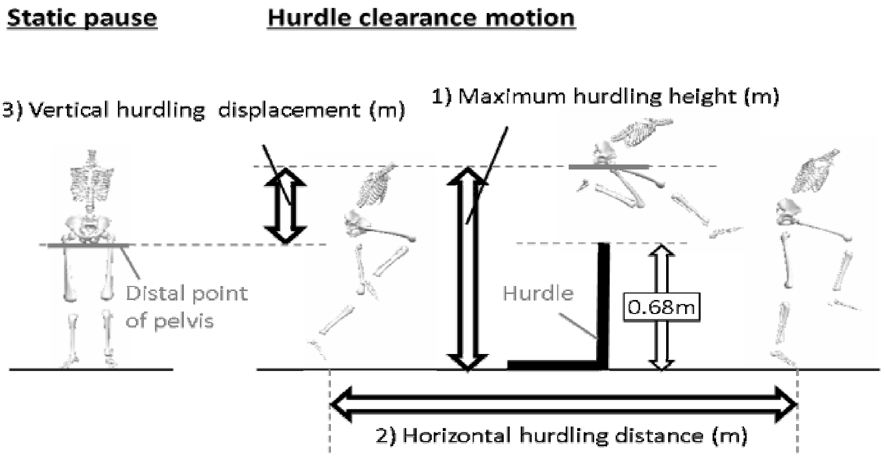

Fig. 1. Analysis parameters on hurdle clearance motion

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)

	Inter-hurdle distance		
	5.5-m	6.0-m	6.5-m
50-m hurdle running time [s]	10.43 ± 0.73	10.25 ± 0.83#	10.14 ± 1.01#
Maximum hurdling height [m]	1.14 ± 0.06	1.13 ± 0.05	1.12 ± 0.05
Horizontal hurdling distance [m]	2.17 ± 0.20	2.29 ± 0.18#	2.38 ± 0.20#
Vertical hurdling displacement [m]	0.30 ± 0.05	0.29 ± 0.05	0.29 ± 0.07

Significant difference from the variable in 5.5-m inter-hurdle distance ($P < 0.05$).

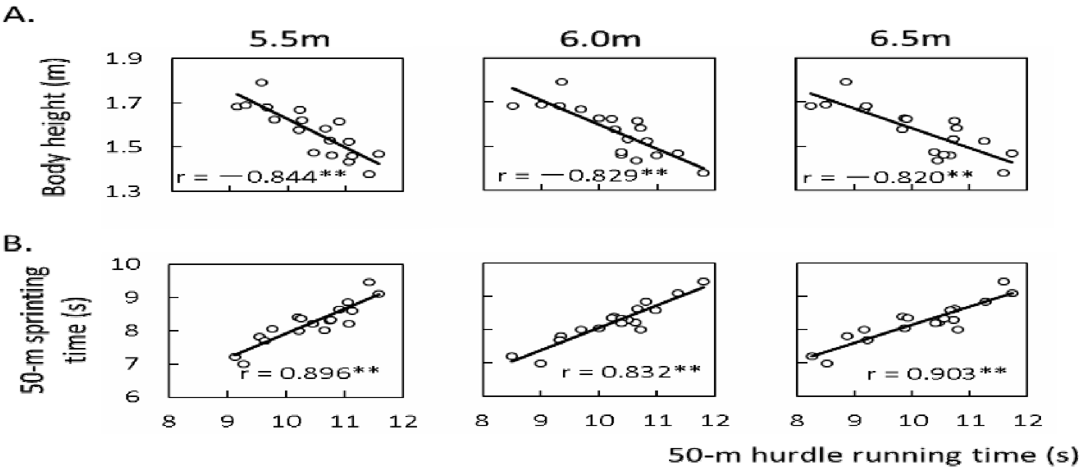

Fig. 2. Relationships of the 50-m hurdle running times between body height (panel A) and 50-m sprinting time at 5.5-, 6.0-, and 6.5-m inter-hurdle distances (panel B). **: $P < 0.01$.

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.

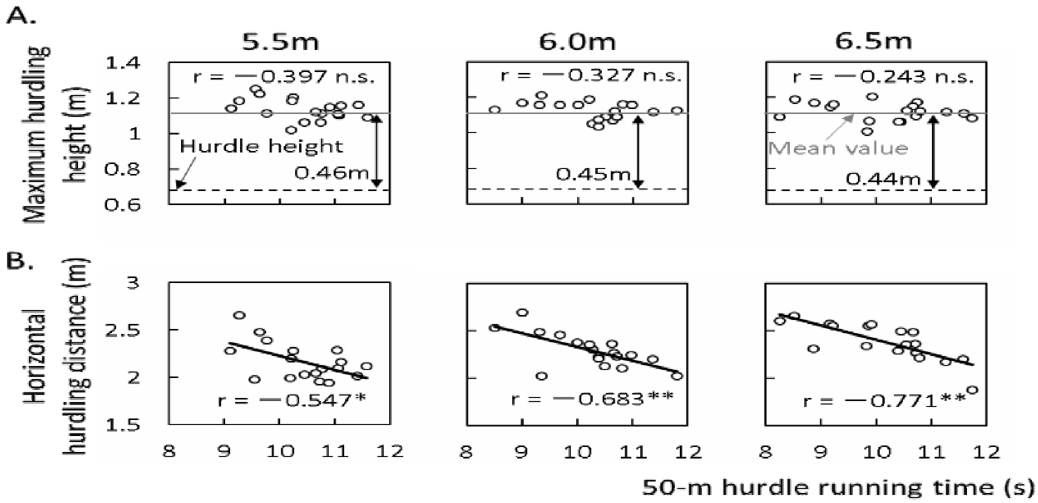

Fig. 3. Relationships of the 50-m hurdle running times between the maximum hurdling heights (panel A) and horizontal hurdling distances at 5.5-, 6.0-, and 6.5-m inter-hurdle distances (panel B). Black dashed lines show the hurdle height (0.68 m). Gray solid lines show the mean values of maximum hurdling 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.

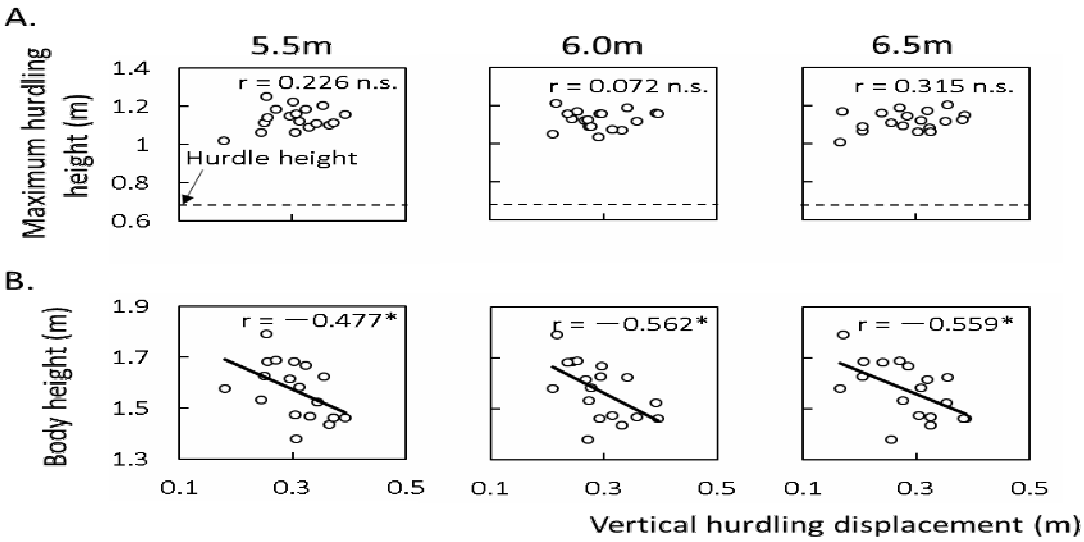

Fig 4. Relationships of the vertical hurdling displacements between the maximum hurdling heights (panel A) and body height at 5.5-, 6.0-, and 6.5-m inter-hurdle distances (panel B). Black dashed lines show the hurdle height (0.68 m). *: $P < 0.05$; n.s.: no significance.

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

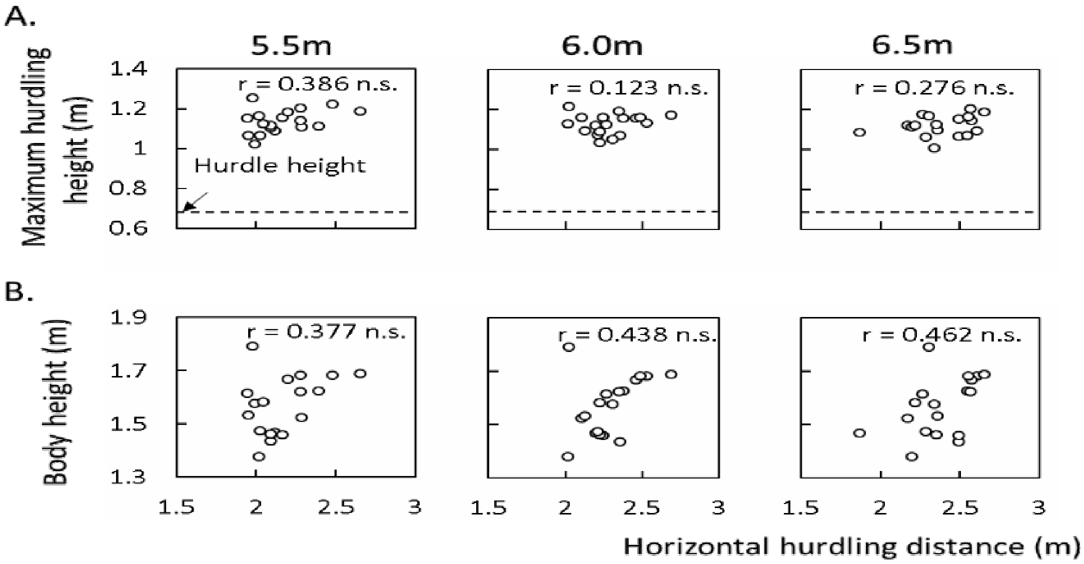

Fig. 5. Relationships of the horizontal hurdling distances between the maximum hurdling heights (panel A) and body height at 5.5-, 6.0-, and 6.5-m inter-hurdle distances (panel B). Black dashed lines show the hurdle height (0.68 m). n.s.: no significance.

Discussion

Recommendations for Instructional content for hurdle clearance motion

In all inter-hurdle distances, the boys who had shorter 50-m hurdle running times had greater body height (Figure 2-A) and shorter 50-m 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 50-m 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