Development of Running and Footwork Abilities from a Viewpoint of Jumping Ability Characteristics

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The purposes of the present study was to investigate the age-related development of fundamental running and footwork abilities from a viewpoint of jumping ability characteristics used by Endo et al. (2007). A total of 389 boys (12 yr: 85, 13 yr: 72, 14 yr: 60, 15 yr: 53, 16 yr: 57 and 17 & 18 yr: 62) conducted counter movement jump (CMJ) and five-repeated rebound jump (5RJ). CMJ and 5RJ abilities were evaluated by jump height and RJ-index (jump height/contact time), respectively. Fundamental running and footwork abilities were assessed 50 m run, 20 m shuttle run and lateral side-step. Division of jumping ability types were as follows: CMJ ability corresponded to RJ ability (Even type), RJ ability was superior to CMJ ability (RJ type) and CMJ ability was superior to RJ ability (CMJ type). 50 m run, 20 m shuttle run and lateral side-step in RJ type were significantly higher performances than those in CMJ type and Even type. This result revealed that fundamental running and footwork abilities in RJ type developed at a high level compared with CMJ type and Even type after the onset of growth spurt and suggest that the assessment of jumping ability using CMJ and RJ is useful to evaluate the physical fitness and motor ability for children.

Keywords: rebound jump, counter movement jump, 50 m run, 20 m shuttle run, lateral side-step

1. Introduction

Physical fitness and motor ability in children have exhibited a continuous declining trend since 1985 (Nishijima et al., 2003). In response to this, the Ministry of Education, Culture, Sports, Science, and Technology (MEXT) in 2000 announced the Basic Plan for the Promotion of Sports, revised in 2006, and has set a major goal of enhancing children’s physical fitness and fostering the attributes and physical fitness necessary to enjoy sporting activities throughout their lifetime. MEXT has also implemented measures including a plan for comprehensive enhancements of athletic performances in international competitiveness. In order to achieve these goals, it may be necessary to appropriately evaluate children during the growth process for their abilities to perform movements fundamental to a variety of sports, and to appropriately enhance such abilities depending on their growth and development.

Jumping motions, which are fundamental physical movements inherent to a variety of sports (Fukashiro, 1997), are frequently used as competitive events, such as the long jump and the high jump, and as exercises for evaluating the ability to exert lower limb strength and training exercises for enhancing these abilities, including the vertical jump and the standing long jump. Zushi et al. (1993) reported that in college athletes of various sports, the force exertion characteristics of the lower limbs can be more appropriately evaluated by assessing jumping ability such as the drop jump that is performed in a very short contact time, in addition to maximum muscle strength, the capacity of the counter movement jump (CMJ), so-called vertical jump (this capacity is hereinafter referred to as “CMJ ability”). On the other hand, previous evaluations of development in jumping ability have primarily assessed the CMJ ability. In this connection, our research group attempted
to evaluate the development in jumping ability by assessing the capacity of the rebound jump (RJ) that was performed in a very short contact time (referred to as “RJ ability”), in addition to the CMJ ability (Endo et al., 2007). We reported that both the CMJ and the RJ abilities developed with age, whereas the RJ ability relative to the CMJ ability varied. The evaluation of the RJ ability relative to the CMJ ability employed a method in which the division of jumping ability types (i.e., the CMJ ability evenly corresponds to the RJ ability, or which was relatively superior to the other) was conducted based on ±1 SD of the residual from a regression equation using both abilities of 1,137 boys aged 6 to 18 years old. As a result, the dispersion between the abilities tended to increase and the individual differences in the jumping ability types were spread, after the onset of the growth spurt. This means that the divisional method using a regression equation reported by Endo et al. (2007) can potentially evaluate the jumping ability types taking into consideration the longitudinal process of the development in individual jumping ability, suggesting that this method may be useful for the evaluation of physical fitness of children during the growth process.

For children during the growth process, it is important not only to enhance the physical fitness in a balanced and overall manner but also to implement enhancement of physical fitness and motor ability on an individualized basis in an organized and planned manner (Takamatsu, 2005). By assessing the previous mentioned the CMJ and the RJ abilities additionally, the characteristics of jumping ability represent individual physical fitness characteristics in children. In order to obtain useful findings for implementing the enhancement of the physical fitness and motor ability of children, it may be important to determine how such jumping ability-based physical fitness characteristics reflect physical fitness and motor ability other than jumping ability.

The purpose of the present study is to determine jumping ability characteristics based on the relationship between the CMJ and the RJ abilities using Endo et al. (2007)’s method and investigate the development of running and footwork abilities on children from the viewpoint of jumping ability characteristics. Since that jumping ability characteristics were reported to be dispersed after the onset of the growth spurt (Endo et al., 2007), junior high pupils and older boys corresponding to this period were selected for the present study.

2. Methods

2.1. Subjects

The participants in this study were 389 boys aged 12 to 18 years old randomly selected from their junior high or high school (Table 1). A subject’s age was obtained at the time of measurement. Because the measurement was conducted in April, 18-year-old subjects were an extremely small population of 17 boys. Thus, in the present study, the 18-year-old subjects were included in the 17-year-old group (62 subjects) for analysis. At the beginning of the measurement, we fully explained the purpose, methods, and measurement safety of the present study to the subjects and their physical education teachers, and then obtained their consent to participate in this study.

2.2. Measured movements

In order to assess jumping abilities, 5-repeated rebound jumps (5RJ) and counter movement jumps (CMJ) were used. 5RJ consisted of repeated jumps upward off the ground from a standing posture; CMJ consisted of jumps with a counter movement (with no restriction on knee flexion angle) from a standing posture. Both jumping movements were performed in a posture where the hands were kept on the hip to exclude the involvement of arm-swinging movements. Before the measurement, the subjects were instructed to perform warm-up exercises adequately and to practice the measurement movements by reference to the demonstration of track and field sprinters familiar with the measurement movements of the present study. For 5RJ performance, the subjects were orally instructed to shorten the contact (support) time as much as possible and jump as high as possible; for CMJ performance, to jump as high as possible.

The 50-meter run, 20-meter shuttle run (reciprocating endurance run), and lateral side step, in the new physical fitness test items (Ministry of Education, Culture, Sports, Science, and Technology: MEXT, 2000) were employed as indicators for physical fitness and motor ability, because of their major association with lower limb ability. All measurements were conducted utilizing the physical education class hour in the subjects’ school under the supervision of their teachers.
2.3. Measurement items and methods

As the indicator for the capacity of each jumping movement, an RJ-index was employed for 5RJ, and jump height for CMJ. All jumping movements were performed on a matswitch (Multi-Jump Tester, DKH Inc.) for measurement of flight time and contact time. The jump height was calculated by substituting the flight time into the following equation (Asumssen & Bonde-Perterson, 1974):

\[
\text{Jump height} = \frac{1}{8} \cdot 9.81 \cdot (\text{Flight time})^2
\]

where 9.81 denotes the acceleration of gravity (m/s²).

The RJ-index was calculated based on the jump height divided by the contact time. The measurement of each jumping movement consisted of 2 trials of jump, and we used the trial that gave jump height or RJ-index the highest value for the analysis.

For the items of the new physical fitness test, the running time was measured (in seconds) for the 50-meter run, the total number of turning around (in times) for the 20-meter shuttle run, and the number of times of stepping over the lines (in points) for the lateral side-step, according to the guideline for implementing the new physical fitness test (for people 12-19 years of age; MEXT, 2000).

2.4. Evaluation of jumping ability characteristics

The characteristics of the jumping ability were determined based on the regression equation (RJ-index=4.217 · CMJ (m)+0.111) reported by Endo et al. (2007) for the CMJ jump height and RJ-index of 1,137 boys aged 6 to 18 years old and ±1 SD of the residual from the regression equation. Then, by inserting the values from the subjects of the present study into the regression equation, the jumping ability characteristics were divided into the following three types: the RJ type, in which RJ ability was relatively superior (n=71), the CMJ type, in which CMJ ability was relatively superior (n=72), and the Even type, in which CMJ ability corresponded to RJ ability (n=233).

2.5. Statistics

The means and standard deviations of the measurement items were calculated. One-way analysis of variance (ANOVA) was used for testing significant differences between ages; and two-way analysis of variance [ages (from 12 to 17 and 18 years old)×jumping ability types (RJ, Even, and CMJ)] was used for testing significant differences between the CMJ jump height, RJ-index, 50-meter run time, total numbers of turning around in the 20-meter shuttle run, and numbers of times of stepping over the lines in the lateral side-step. Additionally, in the case of items having a significant F value, multiple comparison was conducted using Scheffe’s test. For all analyses, the significant level was set at p<0.05.

3. Results

Table 1 shows the physical characteristics and jumping ability in the subjects. Body height and weight exhibited a large increase between 12 and 13 years old, and subsequently a gradual increase significantly every 2 or 3 years until 17 and 18 years old. For jumping abilities, the CMJ jump height and the RJ-index and jump height in 5RJ tended to develop with increasing age until 16 to 17 and 18 years old, exhibiting a significant increase every 2 or 3 years. On the other hand, the contact time in 5RJ exhibited no change with age.

Figure 1 shows the aging courses of the 50-meter run, 20-meter shuttle run, and lateral side-step. All exercises developed, exhibiting increasing results with increasing age. For the 50-meter run, the 13- to 16-year-old groups significantly differed from the 12-year-old group, and the 17 and 18-year-old group from the 13-year-olds and younger and the 15-year-old groups. For the 20-meter shuttle run, the 13- to 15-year-old groups significantly differed from the 12-year-old group, and the 16-year-old group from the 15-year-old group. For the lateral side-step, a statistically significant improvement was observed every 2 years.

Figure 2 shows the body height and weight for each jumping ability type. Both averages were almost the same in all types, with no statistically significant difference.

Figure 3 shows the CMJ jump height, the RJ-index, jump height, and contact time in 5RJ. Significant main effects were observed for both age and jumping ability type and no two-way interactions were observed between them. As a result of multiple comparison regarding jumping ability types, the CMJ jump height was significantly different between the CMJ and Even type. On the other hand, the RJ type had significantly high values of the RJ-index and jump height and a significantly low value of the contact time in 5RJ.
compared to the other two types. Figure 4 shows the 50-meter run time, total number of turning around in the 20-meter shuttle run, and number of times of stepping over the lines in the lateral side-step. For all exercises, significant main effects were observed for both age and jumping ability type and no two-way interactions were observed between them. As a result of multiple comparison regarding
jumping ability types, the RJ type showed significantly high values of all exercises compared to the CMJ and Even types.

4. Discussion

In the present study, the CMJ jumping height, RJ-index, and the present test items of physical fitness and
motor ability each exhibited a developmental trend with increasing age (Table 1 and Figure 2). The values of jumping ability were consistent with those of Bosco and Komi (1980) and Endo et al. (2007), and the measured values of the 50-meter run, 20-meter shuttle run, and lateral side-step were comparable or slightly high compared to the national averages (MEXT, 2005). These results indicate that the subjects of the present study have normal physical fitness and motor ability.

The body height and weight were compared among the jumping ability types in this study. This was because from the report that physique affected the force exertion in the growth process (Malina & Bouchard, 1991), factors other than jumping ability characteristics would affect differences of physical fitness and motor ability if morphologic differences were observed among the types. In the present study, however, the averages of body height and weight were almost the same in all types, with no statistically significant difference (Figure 2). This indicates that it is possible to determine how jumping ability characteristics affect running and footwork abilities.

We here employed and assessed the 50-meter run, 20-meter shuttle run, and lateral side-step in the new physical fitness test items. As a result, the 50-meter run, 20-meter shuttle run, and lateral side-step were all found to show a significant main effect for age and jumping ability type. Multiple comparison regarding the jumping ability types revealed that the 50-meter run, 20-meter shuttle run, and lateral side-step all provided a significant good performance for the RJ type compared to the Even and CMJ types (Figure 4). These findings indicate that running and footwork abilities develop with increasing age after 12 years old and especially that the RJ type remains to a higher level. The RJ type, considering its characteristics, had a slightly lower CMJ ability but a remarkably higher RJ ability with a significantly shorter contact time yet a significantly high RJ jump height than the CMJ type, as shown in Figure 3. Although a higher jump height requires a greater impulse to be obtained (Ae & Shibukawa, 1983), a shorter contact time is presumed to affect achievement of the greater impulse negatively. However, the results of the RJ type were not consistent with that presumption, suggesting that the RJ type may obtain a greater impulse despite a shorter duration through the capability to exert a steeper force rise and a greater peak force. This leads to the assumption that the RJ type may have not only the CMJ ability but also the ability to perform movements and even exert a greater force in a shorter time.

For the 50-meter run, the support time during the maximum sprint run is as short as 0.1 minutes, and those with a faster sprint speed were reported to have the ability to exert greater forces of deceleration and acceleration in a shorter time (Fukuda & Ito, 2004). This is also applicable to children, and children with excellent sprint ability were reported to achieve a significantly shorter contact time and a significantly longer stride length than general children (Kato et al., 2001). The lateral side-step is an exercise of shuttling by side-stepping between the 100 cm bilaterally arranged lines as quickly as possible for 20 seconds. A high score of 60 points requires the time taken for 1 point (equivalent to 2 steps in many cases) to be shortened to 0.33 seconds or shorter, assuming that the combined time of support and flight taken for one step is an extremely short time of 0.17 seconds. Thus, it was assumed that because the 50-meter run and lateral side-step were events that require the abilities not only to exert a great force but also to exert that force in as short a time as possible, the RJ type achieved better results. The 20-meter shuttle run is also an exercise that has been employed for the evaluation of endurance. However, this measurement exercise is a running exercise that was recently reported significant negative correlation between running efficiency, a factor for enhancing long distance running performance, and the RJ ability and thereby allow for improving endurance running capacity by enhancing the RJ ability (Zushi, 2000; Robert et al., 2003; Saeki, 2006). In line with these thoughts, the RJ-type children in the present study could have performed a running exercise efficiently based on their good RJ ability and, if the endurance running capacity were evaluated by the 20-meter shuttle run, would presumably have exhibited a good result. These findings and discussion may suggest the effect of the RJ ability on running and footwork abilities. However, this suggestion is not beyond speculation, because there have so far been few reports on the RJ ability of children during the growth period and also the relationship of the RJ ability to running and footwork abilities has not been studied adequately. Additionally, because the present study did not have sufficiently large numbers of subjects at the respective ages, it was difficult to discuss the characteristics of these ages. Future studies will require further evaluation of each age group for the relationship of the RJ ability to running and footwork abilities and the causal structure.
In this study, research findings demonstrated that the RJ-type children overall had good running and footwork abilities. Studies of the RJ ability among adult athletes reported that track and field sprinters and jumpers abilities or ballgame players abilities of quick footwork could be appropriately evaluated (Zushi et al., 1993; Hennessy & Kilty, 2001; Iwatake et al., 2002), whereas the findings of the current study suggested that children during the growth process could be more appropriately evaluated for their fundamental running and footwork abilities by assessing the RJ ability, which has never been taken into consideration, in addition to the CMJ ability. Regarding children, it is desirable to enhance their physical fitness with participation in exercises through learning and practice of training methods, while defining their goal based on their physical growth and other individualized issues. In this respect, the CMJ and the RJ abilities-derived Endo et al. (2007) regression equation we employed in the present study not only could define the individualized issues, while longitudinally evaluating children for their jumping ability, but also seems to be useful material for more appropriate evaluation of the children's physical fitness and for examination of their training vision because the determined jumping ability characteristics reflected running and footwork abilities. A future issue is to study the method and planning for comprehensively enhancing physical fitness and motor ability depending on the growth stage, by adding a longitudinal survey and training intervention that utilize the evaluation method using this regression equation. Further, by re-evaluating the jumping ability of elite athletes in a variety of sports using the evaluation method of jumping ability used in the present study is useful for setting goals and selection of sports based on children's personal jumping ability characteristics (talent scouting).

In conclusion, it was suggested that evaluation of the jumping ability characteristics based on the relationship between the CMJ and the RJ abilities was found to reflect fundamental running and footwork abilities, and is potentially a useful method for evaluating children’s physical fitness characteristics.

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