EFFECTS OF ROPE LENGTHS ON JUMP CYCLE DURING SKIPPING

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This study determined the effects of different jump-rope lengths on jump cycles while skipping rope. Twelve college students performed the basic jump using three ropes of differing lengths (1.30, 1.39, and 1.48 times their height; short, middle, and long rope, respectively). Cycle time, contact time, and take off time were measured using a switch mat, and coefficient variations (CVs) during 50 consecutive skips were calculated. Cycle time rapidly increased along with take off time when exceeding the middle length of rope ($P < 0.05$). Also, significant correlations were observed between take off time and its CV for short and middle rope conditions (both $P < 0.05$). Thus, results suggested that the long rope could lead to longer take off time (higher jump), and stable jumping would be achieved by higher jumping when using the middle or short rope.

KEY WORDS: rope skipping, jumping cycle, cycle time, coefficient of variation

INTRODUCTION: Rope skipping requires no special equipment nor large space. It is simple cyclic exercise, enjoyed at little cost. Rope skipping is not only a type of children's play (Huang et al., 2010), but is also practiced in schools (Ha et al., 2014). Continuous rope skipping requires stamina because its energy cost is relatively high (Town et al., 1980; Quirk & Sinning, 1982), corresponding to running. Furthermore, several studies on the effect of training on cardio-respiratory endurance have been reported (Jones et al., 1962; Buyze et al., 1986). In addition, the mechanical stimulus of cyclic jumping during rope skipping brings the benefit of increased bone density (Arnett & Lutz, 2002; Gray et al., 2013). Thus, rope skipping can be an effective means of physical training.
In the movement of rope skipping, the relation between physiological or biomechanical variables and the cycle frequency of rope skipping has been investigated. However, no significant differences in energy cost among various cycle frequencies have been found (Town et al., 1980; Myles et al., 1981; Quirk & Sinning, 1982), except at extremely high frequency (Quirk & Sinning, 1982). However, Yamaguchi et al. (2000) reported on the effect of skipping rates (cycle frequency) on ground reaction force, observing the lowest vertical peak force at 92 skips/min. Yamaguchi et al. (2002) also reported that use of muscles and tendons' elastic component increased the skipping rates to more than 100 skips/min. Skipping rates are normally self-selected, but in the studies mentioned above, they were set with a metronome. Azuma (2016) reported that different diameters and weights of rope caused changes in the self-selected cycle frequency of rope skipping. This implied that the rope might be a determinant of cycle frequency, but the relation between rope length and cycle frequency of skipping has not yet been investigated. Most beginners in rope skipping seemed interested in adjusting the rope length. Possibly, identifying the relationship between rope length and cycle frequency during skipping might be quite a fundamental issue for those who intend to start it or to use it for training.
This study aimed to determine effects of different rope lengths on jump cycles while skipping rope.

METHODS: Participants were 12 healthy, physically active college students: males aged 15–20 (Means ± SDs of age: 17.7 ± 1.6 years old, height: 1.73 ± 0.04 m, weight: 58.0 ± 4.7 kg). This study followed the Declaration of Helsinki; that is, all participants received explanation of the experiment's purpose and procedures, including all possible risks. Finally, written informed consents were obtained.
Then, participants were instructed to skip rope using three different lengths of rope. Ropes used in this study were products available in Japan, made from polyurethane rubber (diameter:

5 mm, weight: 22 g/m) with lightweight grips at each end. The lengths were 1.30 (SR, short rope), 1.39 (MR, Middle rope), and 1.48 (LR, long rope) times the participants' height. During the preliminary experiment, participants were asked to skip jump using different lengths of ropes, and none of the skippers could jumped using a rope which is shorter than 1.30 times of their height. Hence, the researcher decided to use this rope length as the lower limit length of the ropes (regarded as SR) for the implementation of the experiment. On the other hand, the length of the long rope (LR) was based on the available (sold) longest ropes in the Japanese market which was less than 2.6 m or 1.48 times height of the tallest participant in this study. From this, the LR for this study was defined to be the rope length which is 1.48 times the height of the participant. The length of MR was the average of the LR and SR. Participants performed 50 consecutive skips on a switch mat (0.45 × 0.50 m) using each rope length in which the timing of the contact and take off from the ground were detected electronically. Data were sampled at 1/1000 s using an A/D converter and recorded using a personal computer (Figure 1). A jump cycle was defined as a combination of contact phase and the following take off phase. The contact phase begins when the feet touch the switch mat after the last take off phase ended, and finishes when the feet touches the mat just before the next take off phase begins (Azuma, 2016). Cycle time was calculated as the total of contact time and the following take off time. Each numerical data for the cycle time, contact time and take off time, was the calculated average value of 50 consecutive jumps of the participants. Additionally, the coefficient of variations (CVs) of cycle time, contact time, and take off time were calculated using the following equation:

$$\mathrm{CV}\ (\%) = \mathrm{SD} \cdot \overline{\mathrm{X}}^{-1} \times 100,$$

where SD is the standard deviation, and $\overline{\mathrm{X}}$ is the mean of 50 jumps.

A one-way ANOVA was used to compare all variables (including CVs) in the three conditions of rope length. Post hoc analysis (Holm method) was also adopted to identify the difference among the length conditions when significant differences were found using ANOVA. Pearson product moment correlation coefficients were calculated to assess the relationships between time variables (cycle time, contact time, and take off time), and each CV. A P value < 0.05 was considered significant for all statistical analysis.

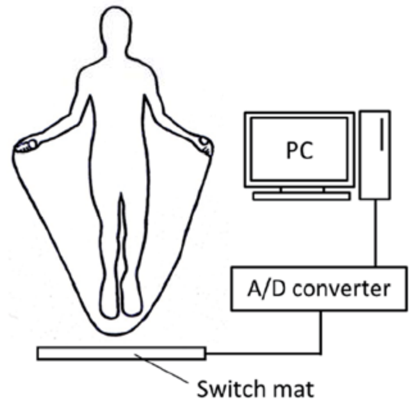

Figure 1: Schematic diagram of the experiment

RESULTS: Figure 2 displays means and SDs for each time variable in the three rope length conditions. Cycle time, contact time, and take off time differed significantly among conditions, respectively (all $P < 0.05$). Cycle time and take off time for LR were longer than for SR and MR conditions (all $P < 0.05$); contact time for LR was longer than for the SR condition ($P < 0.05$). And, there was no significant difference in CVs of each time variable among length conditions ($P > 0.05$). On the other hand, cycle time and contact time in all length conditions were not significantly correlated with those CVs respectively ($P > 0.05$), whereas the relationship between take off time and its CV was significant in SR and MR conditions ($r = -0.847$ and -0.588, respectively; $P < 0.05$, Figure 3).

DISCUSSION: Cycle time rapidly increased when exceeding the middle length. The difference between cycle time for the LR condition and that for the SR condition was associated with both the difference of contact time and take off time between LR and SR conditions. However, the increment of cycle time for the LR condition compared to that of the MR condition may be caused by the increase in take off time. The participants took a longer time jumping rope using LR as compared to using SR and MR. This difference in time may be attributed to the slower completion of a jumping rope rotation by the participants when they were using LR. Hence, it may be possible that the length of the rope affects the temporal (time) variables during skipping.

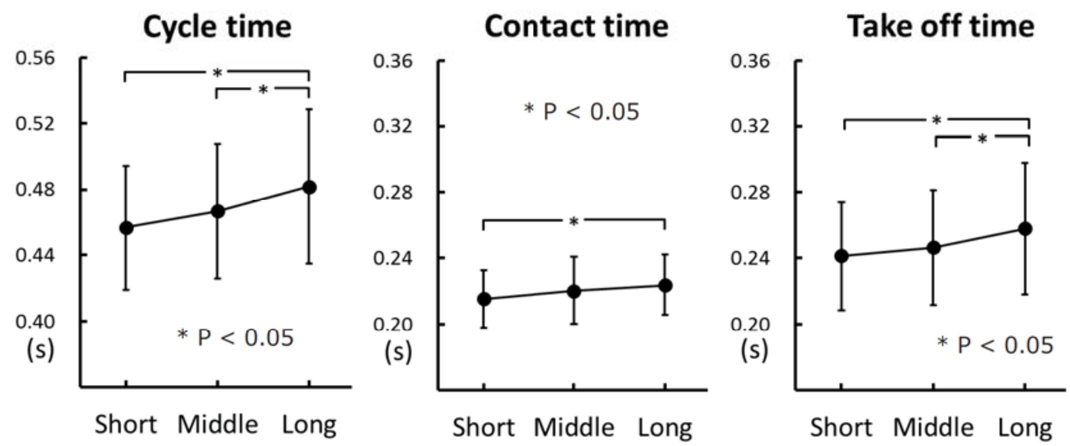

Figure 2: Means and SDs of cycle time, contact time, and take off time for each rope length condition

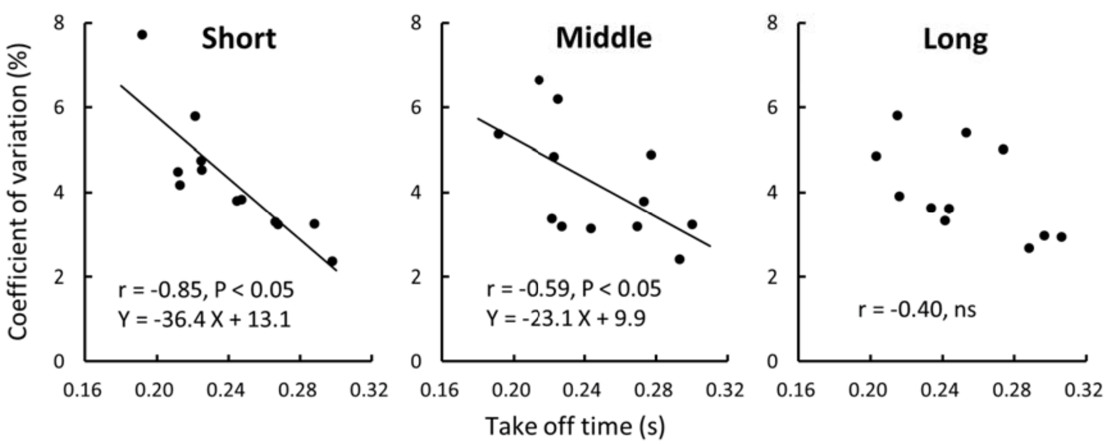

Figure 3: The relationships between take off time and its coefficient of variation in each rope length condition

On the other hand, a significant negative correlation was found only between take off time and its CV in SR and MR conditions. This indicates that participants who performed longer take off time would jump with smaller CV. According to Yamaguchi et al. (2002), the EMG activity of triceps surae muscles disappears early in the plantar flexion phase of the ankle joint with increasing cycle frequency (decreasing cycle time), so that the use of the elastic component of muscle and tendon increases. Conversely, use of muscles and tendons' elastic component decreases and the EMG activity increases when cycle frequency decreases (cycle time increases). It was suggested that greater cycle time would mean greater take off time because R^2 between cycle time and take off time was more than 0.7 in this study. Hence, the use of muscles and tendons' elastic component is lesser, and muscular activity is greater in the jump (skip) with greater take off time (or greater cycle time), according to the report of Yamaguchi et al. (2002). Therefore, for SR and MR conditions, greater muscular activity is assumed to have a significant effect on the stability of higher jumps with longer take off time. Additionally, the difficulty of quick turning and jumping over the rebounding rope might be a cause of CV in take off time, which did not tend to any significant correlation in the LR condition.

Results in this study revealed that the length of rope have effects on the jump cycle during skipping. More specifically, cycle time increased along with greater take off time for middle length of rope. In addition, take off time correlated significantly with its CV when using a middle or shorter length of rope. Hence, as take off time determines jump height, repetitive higher jump training might be planned using longer rope. Referring to data from Yamaguchi et al.

(2000), peak vertical forces are shown as approximately 2.5–4 times the body weight (in the range of 72–132 skips/min). Thus, peak vertical force in a higher jump for the LR condition (average cycle frequency: 125 skips/min) is estimated at approximately 4 times the body weight. The load might be equal to that of the jump in rhythmic gymnastics (4.3 times body weight; Wu et al., 1998). Furthermore, a more stable (skipping) jump is achieved using middle or short rope. It is then established here that the length of the rope is associated to cycle frequency, and does affect the height of jumping (when the rope is longer MR) and its variance (for MR or SR). The long rope causes a higher jump (greater take off time), and a stable jump (take off time with low variance) is led by a higher jump using the middle or short rope. Thus, the choice of rope length is relevant for the kind of training one wishes to achieve using rope skipping.

CONCLUSION: Effects of rope lengths on cycle frequency during skipping were investigated in this study. Results showed that different rope lengths caused significant differences in cycle frequency. More specifically, with a long rope, increased take off time increased cycle time. Furthermore, significant correlations were found between take off time and its coefficient variation when using the middle or short rope. That is to say, a higher jump would lead to a smaller variance in take off time. Thus, the long rope leads to slower cycle frequency (or cycle time becomes longer) and leads to a greater muscular activity of the lower limbs. Possibly, a higher jump (greater cycle time and take off time) would bring stable repetitive jumps when using the middle or short rope. Therefore, the length of rope should be considered to fit the training purpose from the viewpoint of jump height and/or jumping stability.

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