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Original Paper

Effect of the Rotational Speed of a Long Jump Rope in a Person Turning the Rope on Heart Rate and Oxygen Uptake

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Key words: long jump rope, heart rate, oxygen uptake, rope turner

Abstract

The purpose of this study was to clarify the effect of different rotational speeds on the heart rate (HR) and oxygen uptake of a person turning a long jump rope. The subjects consisted of six healthy Japanese males who volunteered to participate in the study. They were asked to turn a long jump rope. The measurement was set at three rotational speed conditions: 70, 90 and 110 rpm. The measurement indexes were HR, oxygen uptake, rating of perceived exertion and blood pressure. The 90 and 110 rpm conditions demonstrated significant HR increases from the first to the third minute of the 3-minute exercise compared with the 70 rpm condition. The 110 rpm condition showed significant HR increases from the first to the third minute compared with the 90 rpm condition. The 90 and 110 rpm conditions demonstrated significant oxygen uptake increases from the first to the third minute compared with the 70 rpm condition. The 110 rpm condition showed significant oxygen uptake increases from the first to the third minute compared with the 90 rpm condition. The changes in the HR and oxygen uptake of the rope turner were dependent on the rotational speed of the long jump rope.

1. Introduction

Rope jumping is a familiar movement that makes use of recoil motion and is an aerobic exercise that has been popularised as a means of maintaining health and physical fitness, which is performed as frequently as walking and running. Rope jumping is defined as a method of turning the rope on your own or playing by jumping over the rope while it is being turned by another person[1]. 'Short-rope jumping' makes use of short ropes, whereas 'long-rope jumping' makes use of long ropes[1]. A short-rope jumping exercise is often the same for the rope turners and jumpers; however, in a long-rope jumping exercise, the rope turners and jumpers are fundamentally different.

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Several elementary schools in Japan integrate long-rope jumping exercises in physical education classes[2]. The elementary school curriculum guidelines include long-rope jumping exercise as an example of exercises with tool manipulation[2]. Short-rope jumping exercise is performed from the first grade, whereas long-rope jumping exercise is performed from the third grade[2]. The body-building movement is an exercise performed to loosen up the body, comprised of the relationship between the mind and the body, by adjusting the condition of the body, interacting with other people and increasing physical fitness[2].

Previous research on short-rope jumping exercise revealed that it is a high-intensity movement[3]. As a training effect of short-rope jumping, Baker reported that a 10-minute rope jumping exercise is comparable to 30 minutes of jogging[4]. Buyze et al. compared the effect between training (5 times a week for 6 weeks) with rope jumping (10 minutes) and jogging (30 minutes) and reported that the maximum oxygen uptake in both groups increased significantly by 7% and 13%, respectively[5]. Rope jumping is more effective in developing endurance in children who do not like to perform endurance running[3,6].

In previous studies on long-rope jumping exercise, there were several reports of teaching-related research[7,8], practical research and lesson study[9,10], but few reports on exercise physiological studies. Therefore, we clarified the changes in the heart rate (HR) and oxygen uptake of turners in long-rope jumping exercise. The HR and oxygen uptake of the turners in long-rope jumping exercise has been reported to be almost constant at a rotational speed of 70 rpm, and the exercise intensity was 3.8 metabolic equivalent of task (MET)[11].

However, there are few reports investigating the physiological responses of a person turning the rope during long-rope jumping exercise. The purpose of this study was to clarify the effect of different rotational speeds on HR and oxygen uptake of a person turning a long jump rope.

2. Methods

2.1 Participants

The subjects consisted of six healthy Japanese males who volunteered to participate in the study. Their age, height and body weight were 22 ± 1 years, 171.7 ± 9.3 cm and 65.8 ± 6.4 kg, respectively [mean ± standard deviation (SD)]. All subjects signed informed consent forms prior to study participation. All procedures were approved by the Ethics Committee of the Kawasaki University of Medical Welfare (15-084) and were in accordance with the Declaration of Helsinki.

2.2 Procedures

2.2.1 Position

The measurement was set at three rotational speed conditions: 70, 90 and 110 rpm. The experimental protocol required the subjects to sit on a chair at rest for 5 minutes, exercise for 3 minutes and rest on a

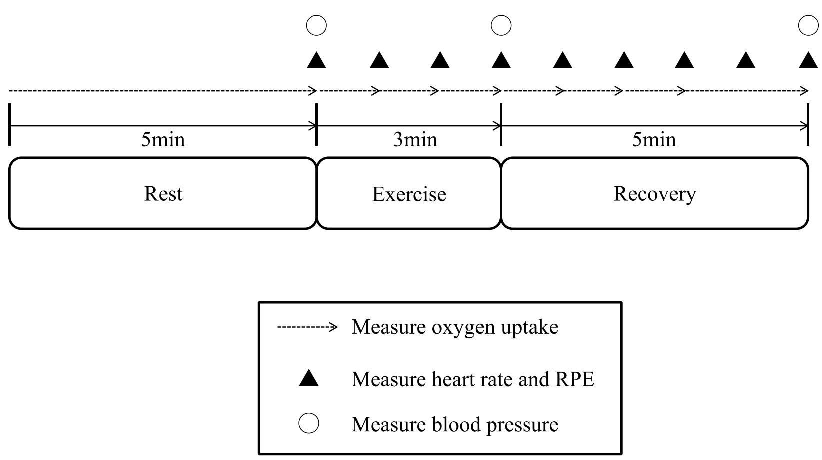

Figure 1　Measurement protocol

chair for 5 minutes. The exercise task was to turn the rope alone. The other side was fixed at the same position as the height of the xiphoid process. A long jump rope (10 m in length) certified by the National Recreation Association of Japan was used. The subjects were asked to turn the long jump rope for 3 minutes in three conditions (Figure 1).

2.2.2 Measurements

(1) HR

The HR was derived over time using a sports heart rate monitor (RS 800 CX; POLAR) and was measured at rest and every minute from the start of exercise.

(2) Oxygen uptake

Oxygen uptake was measured for rest for 5 minutes and measured every minute during exercise. Also, in the recovery period, measurement was made every minute until 3 minutes later, and after that the measurement was performed for 2 minutes. Oxygen uptake was measured using the Douglas bag method. The analysis for oxygen and carbon dioxide concentration of the measured expiratory gas was performed using a mass spectrometer (WASR-1400; Westron) after eliminating exhalation gas bias. Gas quantity and gas temperature were measured with a dry-type gas meter (DC-5; Shinagawa Seisakusho).

(3) Blood pressure (BP)

BP was measured at rest, immediately after exercise and during recovery using an aneroid BP monitor. Blood pressure was measured at sitting position.

(4) Rating of perceived exertion (RPE)

RPE was measured at rest and every minute from the start of exercise to completion of recovery using the Borg scale[12].

2.3 Statistical analysis

Statistical analysis was performed using the statistical software SPSS for Mac ver 23. Data on HR, oxygen uptake, BP and RPE were expressed as mean ± SD. HR, oxygen uptake, BP and RPE were subjected to two-way analysis of variance by repeated measurements, and when an interaction was observed in the pattern of change, multiple comparisons (the Bonferroni method) were performed. The statistical significance level was less than 5%.

3. Results

The 90 and 110 rpm conditions showed significant HR increases from the first to the third minute of the 3-minute exercise compared with the 70 rpm condition ($p < 0.05$). The 110 rpm condition demonstrated significant HR increases from the first to the third minute compared with the 90 rpm condition ($p < 0.05$) (Figure 2). The 90 and 110 rpm conditions showed significant oxygen uptake increases from the first to the third minute compared with the 70 rpm condition ($p < 0.05$). The 110 rpm condition demonstrated significant oxygen uptake increases from the first to the third minute compared with the 90 rpm condition ($p < 0.05$) (Figure 3). The 110 rpm condition showed significant RPE increases at the second and third minute of the 3-minute exercise compared with the 70 and 90 rpm conditions ($p < 0.05$) (Figure 4). There was no significant difference in terms of the change in BP (Figure 5).

4. Discussion

It is reported that the heart rate of short-rope jumping exercise is about 166 to 198 bpm and the oxygen uptake about 38.3 to 49.9 ml / kg / min[13-15]. The HR for 3-minutes of the exercise in this experiment was 114 ± 13 bpm at 70 conditions, 128 ± 8 bpm at 90 conditions and 169 ± 17 bpm at 110 conditions. Oxygen uptake after 3 minutes of exercise was 15.0 ± 4.0 ml / kg / min at 70 conditions, 20.5 ± 4.3 ml / kg / min at 90 conditions and 30.0 ± 4.5 ml / kg / min at 110 conditions. HR of 110 condition showed the same value as short-rope jumping exercise. From this, it was suggested that the exercise intensity is almost the same as that of short-rope jumping exercise of motion by performing rope rotation speed 110 times / min for 3 minutes of exercise. However, oxygen uptake showed a lower value than the short-rope jumping exercise when the long-rope jumping exercise was lower. This means that the hand of the long-rope jumping exercise is a movement with many isometric elements and the short-rope jumping exercise is the movement of many isotonic elements. The isometric element is difficult when working muscle pump action; blood flow may be inhibited. From this, it is considered that the blood flow rate of the hands of the long-rope jumping exercise tends to be slower than the short-rope jumping exercise, so that the cardiac output is maintained by increasing the HR.

METs of each condition were calculated from the oxygen uptake at 3 minutes of exercise. METs were

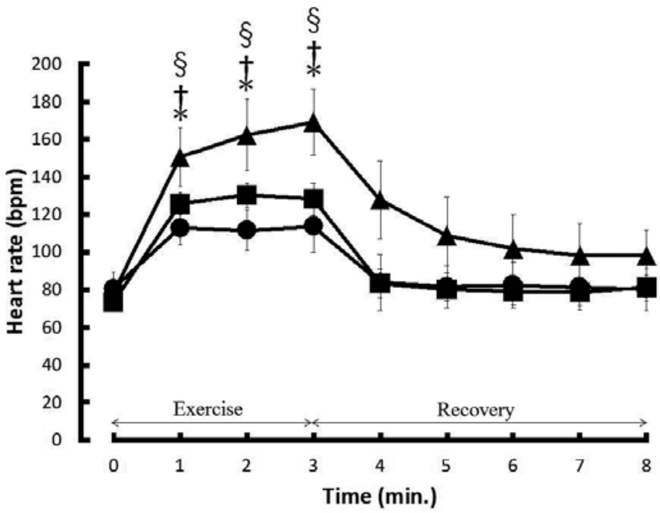

Figure 2 Change in heart rate in the difference of rotation speed (mean ± SD)

● 70rpm condition, ■ 90rpm condition, ▲ 110rpm condition
＊ : 70rpm condition VS. 90rpm condition ($p<0.05$)
† : 90rpm condition VS. 110rpm condition ($p<0.05$)
§ : 70rpm condition VS. 110rpm condition ($p<0.05$)

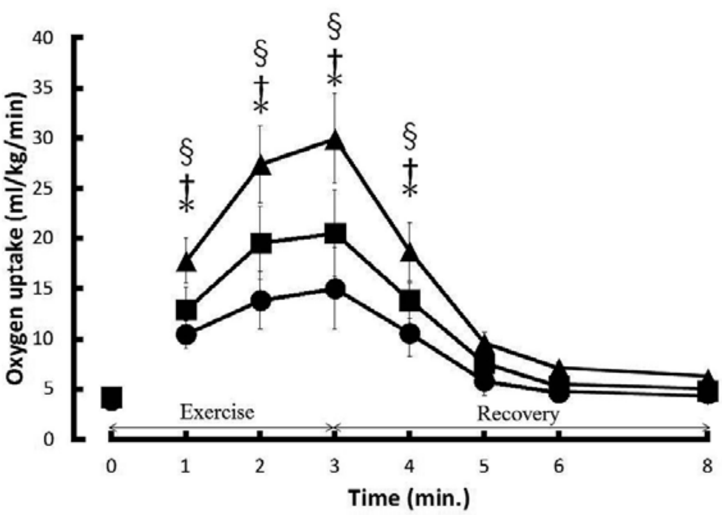

Figure 3 Change in oxygen uptake in the difference of rotation speed (mean ± SD)

● 70rpm condition, ■ 90rpm condition, ▲ 110rpm condition
＊ : 70rpm condition VS. 90rpm condition ($p<0.05$)
† : 90rpm condition VS. 110rpm condition ($p<0.05$)
§ : 70rpm condition VS. 110rpm condition ($p<0.05$)

4.3 ± 1.2 at 70 rpm, 5.9 ± 1.2 at 90 rpm, and 8.6 ± 1.3 at 110 rpm. The rope-turning exercise at 70 rpm had intensity similar to fast walking at 5.6 km/h, indicating that it is a moderate-intensity exercise[16]. The rope-turning exercise at 90 rpm had intensity similar to bicycle running at 15.1 km/h, suggesting that it is a moderate-intensity exercise[16]. Based on these findings, it can be considered that turning the rope for 3 minutes at 70 or 90 rpm is effective as a health promotion exercise. The rope-turning exercise at 110 rpm had intensity similar to running at 8.0 km/h, indicating that it is a high-intensity exercise[16]. Consequently, it is thought that turning the rope for 3 minutes at 110 rpm will lead to an improvement in physical strength level. Because long-rope jumping exercise competition focuses on the number of jumps, it can be implied that the rope turner increases the rotational speed. Based on these findings, it was suggested that the performance of the long-rope jumping exercise in competitions could be improved by training at a rotational speed of 110 rpm or more.

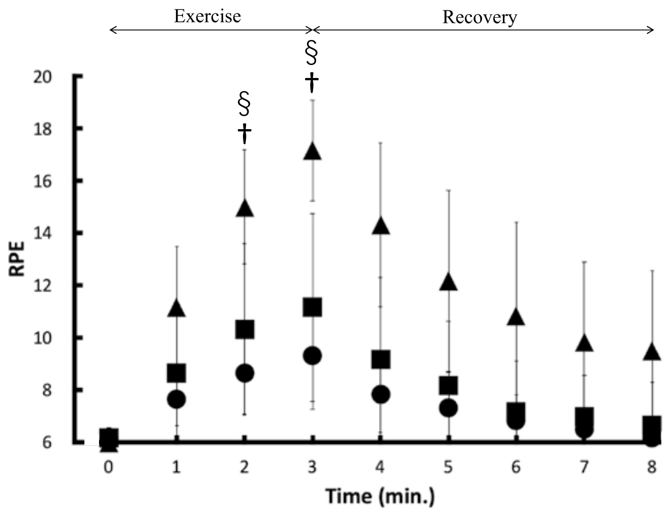

Figure 4 Change in RPE in the difference of rotation speed (mean ± SD)

● 70rpm condition, ■ 90rpm condition, ▲ 110rpm condition

† : 90rpm condition VS. 110rpm condition ($p<0.05$)

§ : 70rpm condition VS. 110rpm condition ($p<0.05$)

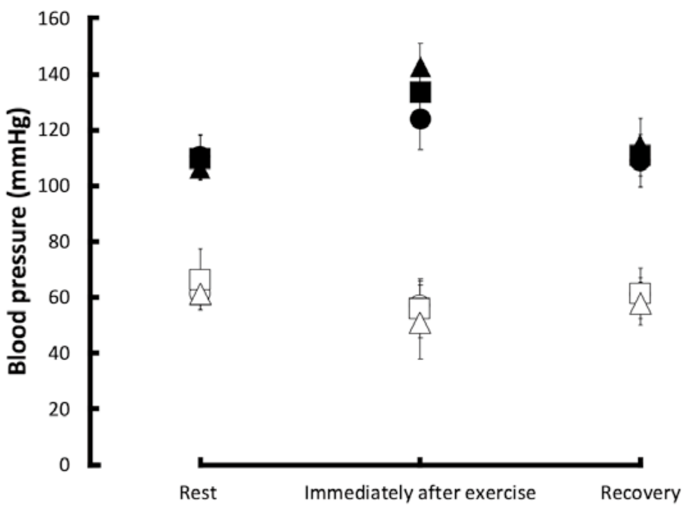

Figure 5 Change in blood pressure in the difference of rotation speed (mean ± SD)

● 70rpm condition, ■ 90rpm condition, ▲ 110rpm condition (Systolic blood pressure)

○ 70rpm condition, □ 90rpm condition, △ 110rpm condition (Diastolic blood pressure)

Previous research reported changes in the HR and oxygen uptake while performing hand ergometer or bicycle ergometer exercises depending on the rotational speed[17]. In this study, the HR and oxygen uptake increased exponentially as the rotational speed increased. It can be considered that the exercise intensity of the turner is limited by the rotational speed of the long jump rope. Therefore, it was suggested that it is necessary to determine the ideal rotational speed of the rope in accordance with the purpose of the exercise while performing long-rope jumping exercises. In the future, we consider that it is necessary to perform the experiment for elementary school children.

5. Conclusion

The increase in rotational speed resulted in increased HR and oxygen uptake, and the change was statistically significant. Thus, the changes in HR and oxygen uptake of the rope turner were dependent on the rotational speed of the long jump rope.

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