CHANGES OF KINEMATICS IN ROPE SKIPPING AFTER FATIGUE

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Rope skipping is a popular indoor exercise which enhances cardiorespiratory fitness. A lot of researches investigated the physiological effects of rope skipping. However, biomechanical analysis in this exercise was limited. The purpose of this study was to compare the changes of kinematics of double-leg forward skipping, before and after fatigue. One male subject participated in the study. The subject skipped for 2 minutes and 55 seconds. Results showed that, after fatigue, the subject decreased the jump height, more trunk and head movement in the forward-backward direction, and might recruit more quadriceps and hamstrings muscles during skip.

KEY WORDS: rope skip, rope jump, fatigue, kinematics.

INTRODUCTION: As rope skipping can be performed indoors, and the equipment is inexpensive, it is an attractive and popular exercise. Previous studies reported physiological effects of rope skipping on human (Myles, Dick, & Jantti, 1981; Quirk & Sinning, 1982; Town, Sol, & Sinning, 1980). However, biomechanical analysis in this exercise was limited (Hortobagyi, Apor, Faludi, Tihanyi, & Merkely, 1986; Pittenger, McCaw, & Thomas, 1999). The purpose of the present study was to compare the changes of kinematics in rope skipping before and after fatigue.

METHODS: One male subject aged 24, with 1.66m height and 70kg weight, participated in the test. The subject was a regular rope skipper who skipped at least one time per week, and at least one hour each time. A master rope skipper was selected to ensure more reliable and consistent movements.
Experimental setup: Two digital cameras (JVC 9600) set at 50Hz sampling frequency were located at the sagittal side and frontal side.
Reflective markers: Twenty-two reflective markers were attached on the subject, locations were: front head, left ear, right ear, jaw, left finger, right finger, left waist, right waist, left elbow, right elbow, left shoulder, right shoulder, left hip, right hip, left knee, right knee, left shoe heel, right shoe heel, left lateral malleolas, right lateral malleolas, left toe and right toe.
Test protocol: Height and weight of the subject were measured at the first, and then 22 reflective markers were attached. The subject was instructed to perform double-leg forward skipping for 5 minutes self-paced in warm up session. Then a double-leg forward skipping test was started with a metronome set at 120beats/min to facilitate subject's performance. The subject was instructed to follow and maintain rhythm and to continue skipping after missed skips. The test was ended until the subject was unable to skip.
Parameters: Height of the center of gravity (vertical distance between ground and the subject's center of gravity), height of toe (vertical distance between ground and toe), ankle angle (angle between the line linking ankle and knee, and the line linking ankle and toe) , knee angle (angle between the line linking ankle and knee, and the line linking knee and hip), hip angle (angle between the line linking knee and hip, and the line linking hip and shoulder, head angle (angle between the line linking the forehead and jaw, and the horizontal direction).
Data reduction: All video from frontal and sagittal cameras were captured into computer for further analysis. Data in first 30 seconds of every minute were used. Ariel Performance Analysis System (APAS, USA) was used in data process.
Procedures were as follow:

1. Trimmed the video so that 10 skips from each time interval were used
2. Digitized the reflective markers of each frame. For the camera located on sagittal side, only markers on the left side were used
3. Used 6Hz digital filter in all direction (X, Y, Z)

Statistical analysis: One-way ANOVA was employed in statistical analysis to compare the mean differences of parameters in each time interval.

RESULTS AND DISCUSSION: The subject skipped about 2 minutes and 55 seconds in the fatigue protocol. Mean value during the lowest position (L) at touch down, the highest position (H) after take off, and the difference between them (H-L) were showed in Figure 1, Figure 2 and Figure 3.

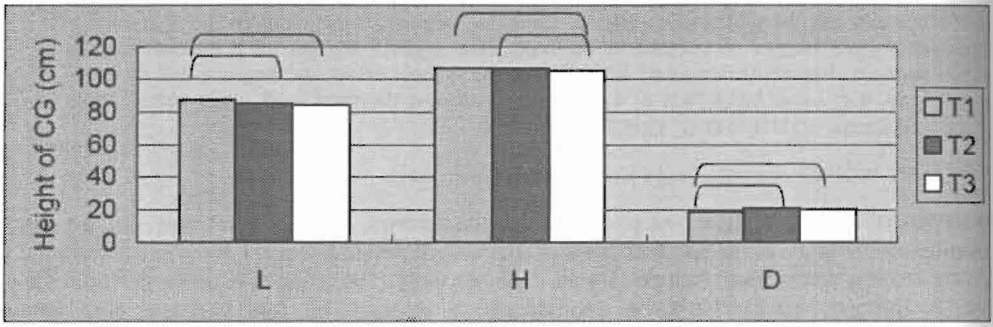

Figure 1: Mean value of height of the CG (center of gravity). The first, second, and third time intervals were showed by "T1", "T2", and "T3". "L" represented the lowest position at touch down; "H" represented the highest position after take off; "D" represented the difference (H-L) between "L" and "H". Significant differences, p<.05, were showed by brackets.

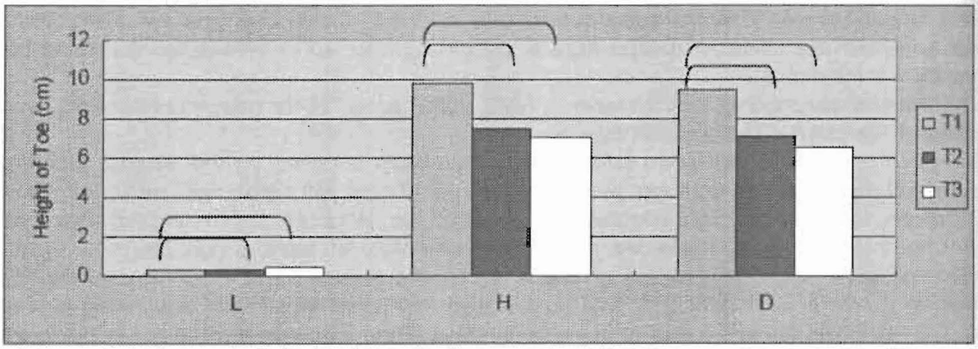

Figure 2: Mean value of height of toe. The first, second, and third time intervals were showed by "T1", "T2", and "T3". "L" represented the lowest position at touch down; "H" represented the highest position after take off; "D" represented the difference (H-L) between "L" and "H". Significant differences, p<.05, were showed by brackets.

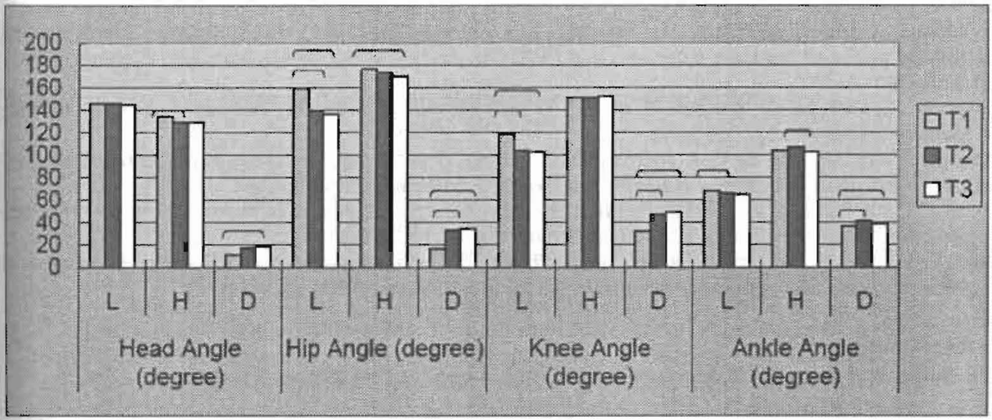

Figure 3: Mean value of head, hip, Knee, and ankle angles. The first, second, and third time intervals were showed by "T1", "T2", and "T3". "L" represented the lowest position at touch down; "H" represented the highest position after take off; "D" represented the difference (H-L) between "L" and "H". Significant differences, p<.05, were showed by brackets.

Changes in center of gravity in the present study were 0.19m, 0.21m, and 0.21m respectively. This was in agreement with Town's study (1980), they reported that average displacement of the center of gravity for male subject at 125 skip/min was 0.211m.

When comparing the results before and after fatigue, three major differences can be obtained. Decreased jump height: Result of height of toe after take off, and height of CG after take off were also decreasing. It showed that after fatigue, subject decreased jump height. It was thought that decreasing jump height would reduce energy consumption. Quirk and Sinning (1982) have analyzed rope skipping at rates of 125skip/min, 135 skip/min and 145 skip/min by cinematographic. They suggested that jump height decreased as rate increased, in order to keep the work output relatively constant. This was in agreement with the present study that the subject decreased jump height after fatigue to maintain a relative constant output.

Recruited more quadriceps and hamstrings muscles: At touch down, result of height of CG, knee angle, and ankle angle were all decreasing. It showed that after fatigue, subject squat lower after landing. It was suspected that subject's lower leg muscles (e.g. calf) were fatigued and so recruited more upper leg muscles (quadriceps and hamstrings) in order to maintain skipping frequency. Myles, Dick and Jantti (1981), showed that all six subjects complained of considerable pain and discomfort, mostly in the muscles of lower leg, when performing a two-minutes self-paced (about 125 times per minute) jumping test. This may explained why the changes in knee angle increased sharply in second interval, as the subject's lower leg muscles were fatigued and need to recruit more muscle from quadriceps and hamstrings, thus he lowered the body at touch down to prepare for next skip.

More trunk and head movements: The differences in hip angle and head angle were increasing. It showed that after fatigue, subject was unable to maintain consistent movement. And more trunk and head movements in the forward-backward direction.

CONCLUSION: The present study compared the changes of kinematics in rope skipping before and after fatigue. Results showed that, after fatigue, subject decreased jump height, more trunk and head movements in the forward-backward direction, and might recruit more quadriceps and hamstrings muscles during skip.

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