

Evaluation of Metabolic Stress between Jumping at Different Cadences on the Digi-Jump Machine

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ABSTRACT

Int J Exerc Sci 3(4) : 233-238, 2010. The American College of Sports Medicine (ACSM) recommends that healthy adults achieve a minimum of thirty minutes of moderate intensity aerobic exercise five days per week. While cycling, walking, and jogging are commonly observed methods of achieving these recommendations, another option may be repetitive jumping. The purpose of this study was to examine the metabolic responses between repetitive jumping at a cadence of 120 jumps per minute (JPMs) vs. 100 JPMs when utilizing the Digi-Jump machine. Twenty-eight subjects completed two jumping trials, one at 120 JPMs and one at 100 JPMs. Subjects jumped until volitional exhaustion, or for a maximum of fifteen minutes. Oxygen uptake (VO₂), heart rate (HR), respiratory exchange ratio (RER), and rating of perceived exertion (RPE) were assessed each minute of each exercise trial. RPE was differentiated, in that subjects reported perceived exertion of their total body, their upper-leg, and their lower leg. Results of this study indicated that there was no significant difference between the two trials for VO₂, HR, or total body RPE. Differences were reported between trials for peak and average RER, with the 120 JPM trial eliciting a lower RER for both (peak: $1.08 \pm .087$ vs. $1.17 \pm .1$ $p=.000$; average: $.99 \pm .076$ vs. $1.04 \pm .098$ $p=.002$), peak upper leg RPE (120: 15.29 ± 3.89 vs. 100: 16.75 ± 2.52 $p=.022$), and average lower leg RPE (120: 15.04 ± 2.55 vs. 100: 13.94 ± 2.02 $p=.019$). Also, there was a significant difference in exercise duration between the trials, with subjects able to exercise longer during the 120 JPM trial (12.4 ± 3.42 mins vs. 9.68 ± 4.31 mins $p=.000$). These data indicate that while the physiological stress may not be different between the two trials as indicated by VO₂ and HR, the 120 JPM trial appears less strenuous as evidenced by RER values and by subjects' ability to exercise longer at that cadence.

KEY WORDS: Repetitive jumping, jump ergometer, cadence

INTRODUCTION

The American College of Sports Medicine (ACSM) recommends that healthy adults should participate in moderately intense aerobic exercise, defined as 64 - 76% of one's maximal heart rate, for at least thirty minutes, five days per week [1,4]. This is

considered the minimum threshold of aerobic exercise for one to maintain health and reduce risk for chronic disease. This exercise may be attained through any number of different means, such as walking, jogging, swimming, or cycling. These activities are likely the most popular and preferred methods of exercise as one

can perform them for various durations, depending upon one's chosen exercise intensity. Another form of aerobic exercise in which people may participate to improve their health is repetitive jumping.

Most people are likely familiar with repetitive jumping, as rope skipping or jumping rope is an activity often observed in elementary school children. Repetitive jumping is an intense activity where the heart rate will often rise quickly after as little as two minutes of jumping [9]. Previous research has demonstrated that this type of activity can contribute to a substantial caloric expenditure as it elicits a high metabolic demand from both aerobic and anaerobic sources, and that regardless of jumping cadence there appears to be no difference in physiological stress [3,5,6,8,11]. However, as these early studies were conducted with subjects turning and skipping a rope, the present study employed the use of a new exercise device specifically designed for repetitive jumping.

An innovative device (the Digi-Jump) has been developed which allows one to use jumping as a training technique without some of the limitations of jumping rope. This device allows one to jump at a pre-determined rate (jumps per minute) and at a pre-determined height per jump, while not having to utilize one's hands and arms, thus possibly reducing localized fatigue and enabling one to continue exercising longer and more consistently. Also, as the jumping rate is governed by a series of lights and audible beeps, one may continue to exercise even if the person has an error. In traditional rope jumping, when the rope catches the foot, one must stop exercising and then start again. This device has only recently been developed and is patent

pending (patent application # 10/464,373). The only previously published research employing this device was a 2008 study by Sivley, et al., which examined the test-retest reliability of this device. Sivley, et al. (2008) demonstrated that the Digi-Jump has test-retest reliability coefficients that are comparable to other commonly used exercise modalities (Absolute VO₂: 0.95; Relative VO₂: 0.71; HR: 0.89; RPE: 0.75) [10].

Early research on rope skipping revealed no differences in metabolic demand between jumping at different cadences, nor did these studies employ a jumping cadence lower than 120 jumps per minute (JPMs) [8,11]. However, those studies used a rope while the present study allowed the subjects' arms to swing freely, and the present study also required subjects to jump at a lower cadence of 100 JPMs. Therefore, the purpose of this study was to investigate the difference in metabolic stress between repetitive jumping at 100 vs. 120 JPMs on the Digi-Jump machine.

METHODS

Subjects

Twenty-eight subjects (18 males and 10 females) between the ages of 18 and 25 years voluntarily completed this study. Subjects were recruited from the local university and city community, and consisted of individuals who were already participating in at least 30 minutes of moderate recreational physical activity on most days of the week. Each subject completed a Physical Activity Readiness Questionnaire (PAR-Q) and a Health Status Questionnaire to screen for any health risk, and ACSM guidelines were employed to eliminate any potential subjects with

known risk factors [1]. Subjects also understood and signed a written informed consent consistent with the requirements of the Western Kentucky University Human Subjects Review Board.

Instruments

All jumping trials were conducted on a Digi-Jump machine. During both exercise trials, metabolic measurements were obtained using a two-way low-resistance breathing valve and a respiratory mask, which covered the mouth and nose. Expired gases were analyzed using a Vacumed Vista Mini-CPX (Vacumed, Ventura, CA). A heart rate monitor was also worn during testing (Polar Vantage XL, Port Washington, NY), and HR was monitored using telemetry. Carbon dioxide and oxygen analyzers were calibrated before each test, using calibration gases of known concentration. The flowmeter was calibrated using a Hans Rudolph (Series 4900) 3.0 L Calibration Syringe (Kansas City, MO). Rating of perceived exertion (RPE) was determined at the end of each minute during each test, using Borg's 15-point scale [2].

Experimental Protocol

Subjects reported to the laboratory for testing on two occasions. They were instructed to report for testing after refraining from strenuous activity for a minimum of 48 hours, and from caffeine, nicotine, and alcohol for a minimum of 24 hours. During the initial visit a thorough explanation of the study was given, along with completion of initial screening procedures and instructions regarding subsequent lab sessions. Subjects were then assessed for height, weight, and percent body fat. Percent body fat was measured based on age, gender and the sum of three

skinfold sites (males: chest, abdomen, and thigh; females: triceps, suprailiac, and thigh) using Lange skinfold calipers [1,7]. Subjects then completed one exercise trial, either at 120 or 100 JPMs. Subjects were instructed to jump at the defined cadence until volitional exhaustion, or for a maximum of fifteen minutes. The second visit consisted only of the remaining exercise trial (120 or 100 JPMs). Jumping trials were performed on separate days in a counterbalanced order with a minimum of 48 hours rest between each.

Statistical Analysis

Statistical Package for the Social Sciences (SPSS) software was used to perform all analyses. All data is reported as mean (M) \pm standard deviation (SD). Analysis of variance (ANOVA) was used to test for differences among subjects' responses from the two exercise protocols. Statistical significance was accepted at $p < 0.05$.

Table 1. Subjects' Physical Characteristics (N=28)

Variable	M \pm SD
Age (yrs)	21.1 \pm 1.8
Height (cm)	170.7 \pm 22.6
Weight (kg)	75.6 \pm 13
Body Fat %	13.6 \pm 5.6

RESULTS

Subjects' physical characteristics are displayed in Table 1. Subjects were lean (body fat 13.6 \pm 5.6%) and reported being recreationally active, but none were competitive athletes nor had any participated in a structured aerobic exercise or training program for a minimum of six months prior to the study.

Table 2. Peak metabolic values.

	120 JPM	100 JPM	p
VO ₂ (ml · kg ⁻¹ · min ⁻¹)	40.88 ± 4.74	41 ± 6.16	.904
HR (bts min ⁻¹)	174 ± 15.95	175.33 ± 16.46	.57
RER	1.08 ± 0.087	1.17 ± 0.1	.000*
RPE _{tb}	15.89 ± 3.44	16.11 ± 3.17	.602
RPE _{ul}	15.29 ± 3.89	16.75 ± 2.52	.022*
RPE _{ll}	17.68 ± 2.78	17.21 ± 2.2	.192

*p<.05

tb = total body

ul = upper leg

ll = lower leg

Table 3. Average Metabolic Values

	120 JPM	100 JPM	p
VO ₂ (ml · kg ⁻¹ · min ⁻¹)	35.63 ± 4.31	35.58 ± 5.02	.956
HR (bts min ⁻¹)	162.49 ± 15.83	161.38 ± 14.24	.591
RER	0.99 ± 0.076	1.04 ± 0.098	.002*
RPE _{tb}	12.95 ± 2.81	12.58 ± 2.24	.338
RPE _{ul}	12.46 ± 2.68	13.21 ± 1.85	.062
RPE _{ll}	15.04 ± 2.55	13.94 ± 2.02	.019*
Exercise Duration (mins)	12.4 ± 3.42	9.68 ± 4.31	.000*

*p<.05

tb = total body

ul = upper leg

ll = lower leg

Tables 2 and 3 depict subjects' metabolic responses to each jump cadence (120 JPM vs. 100 JPM) used for this study. Table 2 reflects peak metabolic values for each trial, while Table 3 displays average values for each trial. Differences in both peak and average RER ($1.08 \pm .087$ vs. $1.17 \pm .1$ $p \leq 0.001$; $0.99 \pm .076$ vs. $1.04 \pm .098$ $p = 0.002$, respectively) were observed across the trials. Though RER values indicated that these protocols were both primarily anaerobic, the slower cadence (100 JPM) appeared to be a significantly more strenuous activity. Differentiated RPE was

collected each minute, and though total body RPE was not different for either peak or average analysis, differences were observed in peak RPE for the upper-leg (15.29 ± 3.89 vs. 16.75 ± 2.52 $p = 0.022$) and in average RPE for the lower leg (15.04 ± 2.55 vs. 13.94 ± 2.02 $p = 0.019$). There was also a significant difference in time to exhaustion between the two trials. Subjects were able to exercise for a longer duration at 120 JPMs compared to 100 JPMs (12.4 ± 3.42 mins vs. 9.68 ± 4.31 mins $p = .000$). Seventeen of the twenty-eight subjects completed the full fifteen minutes on the 120 JPM trial, while on seven of the twenty-eight completed fifteen minutes on the 100 JPM trial. There were no differences observed in VO₂, HR, or total body RPE across trials.

DISCUSSION

The present study examined the differences in metabolic stress between jumping at 120 JPMs compared to 100 JPMs on the Digi-Jump machine. Peak and mean values were analyzed for all variables. Statistics revealed that for both peak and mean values, subjects had similar VO₂, HR, and total body RPE values during the two trials. However, for both peak and mean values, subjects showed a significantly different RER, with the 100 JPM trial being the more anaerobic of the two trials. The 100 JPM trial also resulted in a significantly greater upper-leg RPE when considering only peak values. Lower-leg RPE was significantly higher for the 120 JPM trial when considering average values. There was also a significant difference in trial duration, as subjects were able to sustain the 120 JPM trial longer than the 100 JPM trial.

Considering the differences in RER and the fact that subjects were able to sustain longer

the 120 JPM cadence, the similarities in VO_2 and HR are intriguing. While the subjects were not tested prior to the jumping trials for maximal oxygen uptake, it can be assumed that, based on age-predicted max heart rate and the average HR observed during the trials, that subjects exercised at approximately 80% of their max. However, that might be an overestimation considering the peak and average VO_2 values observed during the trials. The subjects were college-aged, recreationally active college students, and if they reached 80% of max, then that would infer that their max VO_2 would only average around 50 $\text{ml}\cdot\text{kg}\cdot\text{min}^{-1}$, based on peak VO_2 observed. Previous research on rope skipping reported exercise intensities of between 8 – 12 metabolic equivalents (METs) [3, 5, 6, 11], and these Digi-Jump trials, where jumping was done without a rope, elicited similar levels of exertion.

The significantly greater RER found with the 100 JPM trial is consistent with subjective comments provided by subjects following the trials. All subjects commented that the 100 JPM trial was more difficult and resulted in more upper-leg fatigue, due probably to the difficulty in maintaining the slower cadence. This is reinforced by the significantly greater peak upper-leg RPE observed. Though contact time with the jumping platform was not measured, the subjects appeared to experience a protracted eccentric contraction, particularly in the quadriceps and hamstrings, due to the added deceleration required between jumps to follow the slower cadence. A rope skipping study by Quirk And Sinning (1979) did not measure RER, but did measure lactate, and their results revealed higher lactate values elicited from slower cadences [8]. Our

results are consistent with this finding in that the lower cadence (100 JPM) had a greater anaerobic contribution as reflected through the RER measurement.

Subjects were able to exercise approximately 25% longer during the 120 JPM trial compared to the 100 JPM trial. However, subjects did report a significantly greater average lower-leg RPE from the faster 120 JPM cadence. Subjects' comments seemed to suggest that this was due to fatigue in the anterior tibialis region and primarily the result of being able to exercise for a longer duration, thus greater localized fatigue. Post-trial comments were consistent in that while the faster, 120 JPM trial was preferred, it did result in more localized lower-leg fatigue and foot fatigue. A possible explanation for this observed phenomenon is both an increased duration compared with the 100 JPM trial in combination with a greater volume of jumps at the faster rate.

This study examined repetitive jumping at two different cadences on the Digi-Jump machine. Consistent with previous research on rope skipping, repetitive jumping without a rope is also a strenuous activity, regardless of jumping cadence. However, it does appear that jumping at more rapid cadences is preferred and will allow for a more protracted exercise session. Future research in this area should focus on the effects of jumping on different surfaces and the role of repetitive jumping in bone and joint health.

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