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Technical Note

Evaluation of Repetitive Jumping Intensity on the Digi-Jump Machine

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ABSTRACT

International Journal of Exercise Science 13(2): 818-825, 2020. Cardiorespiratory endurance is an important element of aerobic fitness, particularly in weight management and reducing risk for cardiovascular disease. While there are numerous options for aerobic exercise, rope jumping is often overlooked. In addition to regular exercise and a healthy diet, the American Heart Association strongly recommends rope jumping. The first purpose of this study was to determine the steady state metabolic cost of repetitive jumping on the Digi-Jump machine to evaluate whether exercise on this device is more or less strenuous than similar exercise with a jump rope, as demonstrated in previous literature. A second purpose was to determine the relative intensity of exercise on the Digi-Jump by comparing to VO_{2max} as measured on a treadmill. Twenty-seven participants completed two trials, one jumping trial at a rate of 120 jumps per minute with the jumping height set at 0.5 inch for 5-min on the Digi-Jump, and one graded exercise test using the Bruce protocol. Oxygen uptake (VO_2), heart rate (HR), respiratory exchange ratio (RER), and rating of perceived exertion (RPE) were measured each minute during each trial. Results of this study indicated that steady state VO_2 during the 5-min jump test was reached at the 3rd min. Steady state variables during the jumping trial expressed as percentage of max were as follows: VO_2 was 57.1% of VO_{2max}; HR was 80.9% of HR_{max}; RER was 86%of RER_{max}; and RPE was 75.2% of RPE_{max}. These data indicate that repetitive jumping is a strenuous activity and similar in intensity to jumping rope, even if the trial is done on the Digi-Jump machine with free-swinging arms and without a jump rope.

KEY WORDS: Cardiorespiratory, aerobic, cadence, steady state

INTRODUCTION

Cardiorespiratory endurance is considered to be a vital component of a person's overall fitness, and a significant contributor to reducing a person's risk for cardiovascular, pulmonary, or metabolic disease (1). Regular cardiorespiratory exercise results in physiological benefits such as increased blood volume, mitochondrial volume, and capillary density. To elicit these advantageous physiological adaptations, one may consider engaging in rhythmic activities such as running, cycling, swimming, or walking. Along with these, repetitive jumping activities, especially rope jumping (or rope skipping), may also be used to improve cardiorespiratory fitness (17, 18, 21). When discussing the value of regular exercise, the American Heart Association (AHA) strongly recommends rope jumping (2).

Rope jumping is considered a very strenuous exercise. One investigation found that metabolic equivalent (MET) values, or metabolic cost of the activity, ranged from 11.7 to 12.5 when jumping at 125, 135, and 145 jumps per minute (jpm)(21). Another group of researchers suggested that rope jumping requires high demands on both aerobic and anaerobic capacities (18). A limitation of rope jumping, identified by Quirk et al. (1982), is that it requires the arms to hold the rope and coordination of the exerciser to continue to be active (18). Most aerobic exercise modalities have alternative, stationary exercise machines for individuals to complete activity on in a controlled environment (treadmill for walking/jogging/running, cycle ergometer for biking, etc.). Sivley et al. (2008) found the Digi-Jump machine to be reliable (ICC = 0.95), as it simulates the repetitive act of jumping rope while limiting both fatigue and requisite coordination by allowing the arms to swing freely (19).

Using previously determined MET values for traditional jump rope activity, the Digi-Jump can be compared to traditional jump rope activity by evaluating an individual's metabolic cost during steady-state exercise on the Digi-Jump (21). The relative intensity elicited from the Digi-Jump can also be determined during steady-state repetitive jumping exercise by comparing an individual's steady-state values to their measured maximal aerobic capacity (VO_{2max}). As there is not a validated, mode-specific graded exercise test (GXT) designed to elicit an individual's VO_{2max} from repetitive jumping, a treadmill protocol was used as both running and repetitive jumping are weight-bearing, high-impact exercises.

Therefore, there were two purposes to this study. The first purpose was to determine the steady state metabolic cost of repetitive jumping on the Digi-Jump machine to evaluate whether exercise on this device is more or less strenuous than similar exercise with a jump rope, as demonstrated in previous literature. A second purpose was to evaluate the relative intensity of exercise on the Digi-Jump by comparing to VO_{2max} as measured on a treadmill.

METHODS

Participants

Participants (N = 27) were recruited from Western Kentucky University Exercise Science and Physical Education graduate and undergraduate programs. All participants were between the ages of 18 to 44 years, and all completed a physical activity readiness questionnaire as well as a health status questionnaire. Per American College of Sports Medicine guidelines (2018), all participants exercised regularly and none had, nor showed signs or symptoms of, any cardiovascular, metabolic, or renal disease (1). The study sample was considered to be recreationally active, defined by participating in at least 30 minutes of moderate intensity physical activity on most days of the week. Participants were instructed not to consume heavy food for approximately four hours prior to each of the two laboratory sessions. They also were instructed to abstain from alcohol and strenuous exercise for 24 hours prior to testing.

Participants read and signed a written informed consent consistent with the requirements of the Western Kentucky University Institutional Review Board. This research was completed in accordance to the ethical standards of the International Journal of Exercise Science (16).

Protocol
Participants attended two randomized, counterbalanced laboratory sessions separated by 48 – 72 hours. During the first laboratory session, all paperwork and resting variables were collected, including height, mass, and body composition, as well as instructing participants on the Digi-Jump machine and allowing them an opportunity to practice jumping repetitively while maintaining a given cadence. This was important because although jumping is a natural rhythmic movement, jumping at a consistent predetermined pace without any warmup or familiarization could have caused additional stress and possibly an artificially inflated heart rate. Body composition was measured with skinfold calipers (Lange, Beta Technologies, Cambridge, MD) using a standard seven-site protocol (12, 13). Height and mass data were used to calculate body mass index (BMI) for generalizability. Duration of the first laboratory session was approximately 75 minutes, while the duration of the second session was approximately 60 minutes.

To obtain data for the initial purpose, participants completed the repetitive jumping trial on the Digi-Jump machine (figures 1 & 2). After a self-selected warmup, participants engaged in five minutes of repetitive jumping at a jumping height of 0.5 inch and a cadence of 120 jpm on the Digi-Jump machine. Metabolic measurements were obtained through open-circuit spirometry. Expired gases were analyzed using validated metabolic analysis equipment (ParvoMedics TrueOne 2400, Sandy, UT). Carbon dioxide and oxygen analyzers were calibrated before each test, using calibration gases of known concentrations. A heart rate (HR) monitor placed on the chest collected data using telemetry and was worn during all tests (Polar vantage XL, Port Washington, NY). Rating of perceived exertion (RPE) was reported at the end of each minute during the jumping protocol (4).

The GXT for the second purpose employed the Bruce protocol performed on a Trackmaster TMX425C treadmill (Full Vision, Newton, KS). The Bruce protocol was chosen as it has been shown to be both valid and reliable (5, 6, 15). Metabolic measurements using open circuit spirometry as described above were collected also during the GXT. Rating of perceived exertion (RPE) was reported during the last 15 seconds of each three minute stage during the GXT, using Borg's 6-20 scale (4). Participants walked or jogged during the progressively intensifying GXT until volitional exhaustion. Immediate termination of the GXT was granted upon participant request. A GXT was considered to be a valid VO_{2max} test provided two of the following criteria were met: 1. HR reached a level to within 10 beats of the participant's age-predicted max; 2. respiratory exchange ratio (RER) $\geq$ 1.15; 3. a plateau of the subject's VO_2 (increased intensity without proportional increase in VO_2); 4. RPE greater than 17 on the Borg scale.

Statistical Analysis
Statistical Package for the Social Sciences (IBM SPSS version 21.0) software was used to perform all analyses. A post-hoc power analysis conducted with G*Power software (version 3.1,

Universität Kiel, Germany) confirmed with statistical significance set at 0.05, a sample size of 27 was sufficient for a moderate effect size of 0.6 and a power level of 0.98. All data were reported as mean (M) ± standard deviation (SD).

For the initial purpose of this study and to determine steady state, one–way analysis of variance (ANOVA) and Tukey post-hoc tests were used to test for differences between participants' minute-by-minute responses during the repetitive jumping trial. For the second purpose, maximal metabolic variables (VO_{2max}, HR_{max}, RER_{max}) were determined to be the highest value observed during the maximal exertion test, and RPE_{max} was determined to be the last value provided by the participant upon test termination.

Figure 1. Digi-Jump machine

Figure 2. Digi-Jump display panel

RESULTS

The study sample included 27 healthy, collage-aged participants (12 males and 15 females). Participants' physical characteristics are shown in Table 1.

Table 1. Participants' descriptive statistics.

	Age (yrs)	Weight (kg)	Height (cm)	Body Fat (%)	Body Mass Index
All participants	21.7 ± 2.2	70.1 ± 15.6	172.4 ± 9.9	15.9 ± 7.8	23.4 ± 3.7

Note: Values are presented as M±SD

For the first purpose, one-way ANOVA and Tukey post-hoc tests indicated that steady state VO_2 during 5-min of repetitive jumping on the Digi-Jump Machine occurred at the third minute (p <

.05), which was consistent with previous literature (3). At that time point, mean steady state VO_2 was 31.1 ± 5.5 ml/kg/min (8.9 METs), mean steady state HR was 149.2 ± 20.1 beats per minute (bpm), mean steady state RER was 0.99 ± 0.1, and mean steady state RPE was 13.5 ± 1.5. These values were similar to results observed in previous literature (14, 17, 18, 21).

Data collected for the second purpose revealed that steady state jumping values, as a percentage of individuals' max, were as follows: (VO2: 57.1% ± 12.2; HR 80.9% ± 10.6; RER: 86.0% ± 6.0; RPE: 75.2% ± 7.9). Results for maximal exertion tests and 5-min repetitive jumping tests on the Digi-Jump Machine are displayed in Table 2.

Table 2. Comparison between maximal treadmill test variables and Digi-Jump steady state (minute 3) variables.

	VO_2 (ml/kg/min)	METs	HR (bts/min)	RER	RPE
Treadmill max	56.4 ± 12.0	16.1 ± 3.4	184.7 ± 9.9	1.15 ± 0.1	17.9 ± 1.0
Steady-state Digi-Jump	31.1 ± 5.5	8.9 ± 1.6	149.2 ± 20.1	0.99 ± 0.1	13.5 ± 1.5
Steady-state percentage of max	57.1% ± 12.2	[redacted]	80.9% ± 10.6	86.0% ± 6.0	75.2% ± 7.9

Note: Values are presented as M±SD

DISCUSSION

The first objective of the present study was to determine the steady state metabolic cost of repetitive jumping on the Digi-Jump machine, and to determine if exercise on this device is more or less strenuous than similar exercise with a jump rope as described in previous literature (14, 17, 18, 19, 21). The second objective was to evaluate relative intensity of Digi-Jump exercise, based on each person's VO_{2max} as measured on a treadmill. Based on previous literature, we hypothesized that repetitive jumping would yield a metabolic cost of approximately 10-12 METs, and the relative intensity would reflect that of normal, moderate intensity exercise, i.e. 55 – 65% of one's VO_{2max}. The main finding of the present study was that mean steady state VO_2 of jumping was 31.1 ± 5.5ml/kg/min (8.9 ± 1.6 METs), compared to mean VO_{2max} 56.4 ± 12 ml/kg/min (16.1 ± 3.4 METs).

For all participants it was observed that jumping VO_2 was approximately 57.1% of VO_{2max}. However, in a study by Quirk et al. (1982), they compared the metabolic demand during rope jumping to their participants' VO_{2max}, and they discovered that participants were jumping at very high capacities, females – 92% and males 76 – 88% of their VO_{2max} (18). However, in the present study jumping VO_2 was just 57.1%, which could be explained by our participants not jumping with a jump rope, thus not contributing to possible strain in their arm and shoulder muscles. Rather, in the present study the participants' arms were swinging freely. Another consideration that may explain the lower steady state VO_2 is that we evaluated steady state jumping VO_2 as occurring at the 3rd minute of repetitive jumping. Additionally, we did not increase jumping cadence in this study. All participants were jumping at the same cadence, which was 120 jpm with the jumping height set at 0.5 inch. Yet, the study by Perantoni et al. (2009) used a jump protocol that used only the lower limbs at a cadence of 135 bpm and at duration of 10 minutes. Their results showed that participants were exercising at 64% of their measured VO_{2max} (17). Another study used step training at a cadence of 135 bpm, without using upper limbs, and it was found that participants were exercising at 55% of measured VO_{2max} as assessed with a GXT (22).

Similarly we compared HRs during the jumping and maximal exertion tests. Jumping steady state HR for all study participants was 149.2 ± 20.1 bpm, but GXT max heart rate was 184.7 ± 9.9 bpm, showing that study participants during the 5-min jumping test were exercising at approximately 80.9% of their maximal HR. Our findings are consistent with Perantoni et al. (17), which reported that participants jumped at 81% of their max HR as measured during a GXT, and similar to those of Vianna et al. (22), which demonstrated that participants during jump test were exercising at 90% of their GXT measured heart rate. The high HR percentage observed during 5-min of jumping agrees with the previous studies on rope skipping and repetitive jumping (14, 18, 19, 21), which state that repetitive jumping is a strenuous cardiorespiratory activity.

Along with HR and VO_2, we observed steady state RER during repetitive jumping. Jumping steady state RER and GXT RER for all study participants was 0.99 ± 0.6 and 1.15 ± 0.07, respectively. Jumping steady state RER was 86% of the maximal RER obtained during the GXT. As the RER is a significant predictor of anaerobic threshold (19, 20, 23) then these percentages suggest that if all participants during five mins of repetitive jumping were exercising at 84 -88% of maximal graded test RER, then participants in this test were working quite close to their anaerobic threshold.

This study also evaluated participants' steady state rate RPE compared with GXT RPE. Results showed RPE values of 13.5 ± 1.5 and 17.9 ± 1, respectively. That means that participants during 5-mins of repetitive jumping were exercising at approximately 75.2% of their perceived max that was obtained during the GXT. According to the studies performed by Faulkner and colleagues (7, 8), RPE is a significant predictor for VO_{2max}. In our study, 5-min jumping test RPE results were approximately 74 - 76% of participants' VO_{2max} test RPE final result, suggesting that participants during the jumping trial perceived their intensity to be at moderate-high level.

This study confirmed that repetitive jumping on the Digi-Jump machine is a strenuous cardiorespiratory exercise, with results similar to what has been observed in previous literature on rope jumping. While steady state VO_2 on the Digi-Jump appears to be at a moderate intensity level relative to a person's VO_{2max}, HR, RER, and RPE were all at an elevated intensity indicative of vigorous exercise. Further research should be pursued examining these and other physiological variables on the Digi-Jump machine with graded jumping cadences and increased height per jump, as well as examining the efficacy of the Digi-Jump as a training modality for athletes.

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