Cardiorespiratory Response to Exercise on a Large Therapeutic Roll

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ABSTRACT

Purpose: Large therapeutic rolls (LTR) and balls are popular rehabilitation tools and have also been advertised as cardiovascular training devices. The aim of this study was to determine if individuals of varying fitness levels would reach aerobic training levels by evidence-based standards as described in American College of Sports Medicine (ACSM) publications. **Methods:** Fourteen volunteers performed a maximal exercise test and on subsequent days, two submaximal exercise tests on the LTR (LTR-A and -B). LTR-A consisted of four 5-minute stages of exercise at progressive intensity levels. LTR-B included 20 minutes of continuous exercise. Oxygen consumption (VO_2) and heart rate (HR) during exercise on the LTR were compared with ACSM recommended standards. **Results:** The average (range) peak intensity achieved during LTR-A was 66.8% (51.7-82.7%) of maximal VO_2 reserve (VO_{2R}) and 82.9% (70.7%-91.2%) of maximal heart rate (HR_{max}). During LTR-B, HR and VO_2 of all participants was maintained at moderate exercise intensity and averaged 56% of VO_{2R} and 78% of HR_{max} during the 20 minute exercise period. **Conclusions:** These findings suggest that individuals with a wide range of aerobic fitness are able to reach and maintain aerobic training levels with appropriate exercise on a large therapeutic roll or ball.

Key Words: large therapeutic roll, Swiss Ball, aerobic exercise, exercise intensity

INTRODUCTION

The popularity of aerobic exercise has increased over the years as evidence has continued to show the benefits of such activity. Physical training has been found to increase cardiorespiratory fitness, which is associated with numerous

physical and mental health benefits including decreased risk of common chronic diseases such as cardiovascular disease, diabetes, and certain cancers.¹⁻³

To achieve health benefits, current physical activity recommendations by the United States Department of Health and Human Services (ie, 2008 Physical Activity Guidelines for Americans) and the American College of Sports Medicine (ACSM) suggest that adults should perform at least 150 minutes a week of moderate-intensity, or 75 minutes a week of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity aerobic activity.^{1,4,5}

The threshold intensity of exercise needed to improve cardiorespiratory fitness varies depending on the initial state of fitness of the individual. An analysis of 18 clinical trials by Swain and Franklin⁶ suggests a minimal training threshold of at least 45% maximum oxygen uptake reserve (VO_{2R}) is required to improve aerobic capacity ($\text{VO}_{2\text{max}}$) in healthy adults in the average to good fitness category. In deconditioned individuals, this minimal training threshold may be 30% VO_{2R} or lower.⁶ Based on such evidence, the current ACSM's *Guidelines for Exercise Testing and Prescription* advise "Exercise of at least moderate intensity (ie, 40% to < 60% VO_{2R} that noticeably increases HR and breathing) is recommended as the minimum exercise intensity for adults to achieve health/fitness benefits. However, a combination of moderate- and vigorous-intensity (> 60% VO_{2R} that results in substantial increases in HR and breathing) exercise is ideal for the attainment of improvements in health/fitness in most adults."⁵

Large therapeutic balls and rolls were originally used by Swiss physical therapists in the pediatric setting and later in neurologic and orthopedic rehabilitation to increase balance, coordination, functional strength, and flexibility.⁷⁻⁹ American therapists, who were exposed to the "Swiss Ball" in Europe, introduced this mode of exercise in the United States; and in recent years, ball exercise programs have gained increasing popularity in this country. Innovative practitioners now use ball exercises in very creative ways with a variety of patient populations.^{8,10-14} Advertisements and popular literature include claims that therapeutic balls and rolls can be used as cardiovascular

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training tools, although research has not provided evidence for these assertions.¹⁵⁻²⁰ Only one study examined the cardiorespiratory responses to exercise on a therapeutic ball. Cassidy et al.²¹ reported exercise heart rates ranging from 36% to 88% of age-predicted maximal heart rate and energy consumption ranging from 1.7 to 3.9 METs during abdominal stabilization exercises in healthy, young subjects. However, a thorough review of the literature did not yield any studies examining the cardiorespiratory response to aerobic exercise on a therapeutic ball or roll.

The primary purpose of this study was to measure the cardiorespiratory response to aerobic exercise on a large therapeutic roll (LTR) in order to determine if individuals of varying fitness levels would be able to reach and maintain aerobic training levels consistent with ACSM's recommended standards. Due to the novel nature of this mode of exercise and lack of any reports on reliability of measurements of exercise parameters and physiological variables, a secondary purpose of this study was to examine the reliability of oxygen consumption and heart rate, as well as bounce cadence during specific ball exercise activities used in this study.

METHODS

Subjects and Design

Fourteen healthy adults (6 males and 8 females) with a mean age of 27 years (range 19-40) volunteered to participate in this study. Subject recruitment was "by convenience," however, an effort was made to enroll individuals representing a wide range of physical fitness. The participant group included very sedentary individuals, persons participating to varying degrees in recreational physical activities, and one highly trained amateur endurance athlete. Subjects were instructed to present to the laboratory wearing nonrestrictive exercise attire; to abstain from alcohol, caffeine, or food for at least 3 hours prior to testing; and to avoid physical exercise for 24 hours prior to testing. Upon arrival in the laboratory, subjects were asked to complete a comprehensive medical history. Individuals with a cardiovascular, respiratory, orthopedic, or other medical condition that would limit his or her participation in physical activity or pose a medical risk were excluded from participation. Procedures of all tests were explained to the participants before written informed consent was obtained. The study design and consent form had been previously approved by the University of Utah Institutional Review Board.

All testing was conducted in the Clinical Neuromuscular Research Laboratory at the University of Utah. Each subject visited the laboratory three times. During the first visit a maximal exercise test (MXT) was conducted to determine maximal oxygen uptake ($\text{VO}_{2\text{max}}$). After recovery from the MXT participants received instructions regarding exercise on the large therapeutic roll (Physio-Roll; Sportime International, Atlanta, GA) and practiced performance of exercise at all intensity levels until proficiency was demonstrated. On the second visit, subjects performed a submaximal, progressive exercise test (LTR-A) on the LTR

consisting of 4 consecutive 5-minute stages of continuous exercise at increasing intensity levels. The purpose of this test was two-fold: (1) to measure the individual cardiorespiratory response to exercise at each intensity level, and (2) to determine the exercise level that would elicit the most appropriate cardiorespiratory response for exercise training by ACSM standards. On the third visit, subjects performed a submaximal exercise test (LTR-B) to simulate a training session. It consisted of a 5-minute low intensity warm-up, 20 minutes of continuous exercise at an 'aerobic training intensity,' and a 5-minute cool-down period on the LTR. The purpose of this test was to examine if an appropriate aerobic training intensity could be maintained for a 20-minute aerobic training period within a 30-minute aerobic exercise session. Testing for each subject was conducted within a 2-week period with a minimum of 48 hours between tests.

Equipment standardization and reliability testing

Product instructions and authors of Swiss Ball exercise books recommend to fit a ball to a subject so that hips and knees form a 90° angle when sitting on the ball with the feet flat.^{9,22} PhysioRolls are available in different colors corresponding to specific size designations. Product instructions advise to inflate the rolls to the designated model size.²³ However, the authors of this study found that the actual sizes of rolls of the same color (and corresponding size category) and brand may vary significantly. Therefore, in order to standardize the firmness or 'bounciness' of the LTRs, each LTR used for this study was inflated to a standard pressure of 38 mmHG. Inflation pressure of LTRs was measured with a mercurial manometer (Labtron, Model #03-235, Graham-Field Company, Hauppauge, NY) that was connected via a 10-inch piece of blood pressure cuff tubing to a modified factory supplied inflation valve (backflow protection ball removed). Inflation to 38 mmHG resulted in the following circumference measurements (CF)/calculated diameters (D) of rolls used for this study: 4 blue (70 cm) PhysioRolls - CF 213 cm (D 67.8 cm), CF 203 cm (D 64.6 cm), CF 189 cm (D 60 cm), CF 181 cm (D 57.6 cm); 4 yellow (55 cm) PhysioRolls™ - CF 167 cm (D 53.2 cm), CF 157 cm (D 50.0 cm), CF 149 cm (D 47.5 cm), CF 141 cm (D 44.9 cm). Each subject was assigned one of these LTRs based on body size and weight so that recommended size criteria (90° knee flexion angle when sitting on the LTR) was met. Each LTR was marked with an individual code and the same LTR was used for both tests for each subject. Inflation pressures of each ball were measured and if necessary adjusted daily before testing began, and circumference measurements were checked before each test.

Due to the novel nature of this mode of exercise and lack of any reports on reliability of measurements of exercise parameters and physiological variables, a pilot study to examine reliability of VO_2 , HR, and bounce cadence was completed. Four subjects performed the LTR-A test protocol (see detailed description below) 5 times, on 5 different days at least 48 hours apart, within a two-week period. ICC

(2,1) scores were calculated based on the average values observed during the last two minutes of each of the four 5-minute stages of each test.

Measurements

During both the maximal and submaximal exercise tests, expired gases were collected and analyzed using a ParvoMedics Truemax 2400 metabolic measurement system (ParvoMedics, Sandy, UT), which uses a paramagnetic oxygen analyzer, an infrared carbon dioxide analyzer, and a Hans Rudolph Screen Pneumotach flow meter for measuring ventilation (V_E). Before each test, the gas analyzers were calibrated with gases of known concentration, and the flow meter was calibrated with the computerized “Yeh” method using multiple strokes of a precision 3-liter syringe.²⁴

A standard Lead II electrode configuration was used to obtain heart rate and an electrocardiogram (ECG). Heart rate and ECG tracings were displayed on a Fukuda ECG system (Model FCP-2201A, Fukuda, Denshi Co., Tokyo, Japan) as well as on the monitor of the metabolic cart. Heart rate, VO_2 , RER, and other standard metabolic variables were also displayed and recorded by the metabolic system computer in single breath intervals. Twenty second averages of all MXT values and 60 second averages of all LTR-A and B values were exported to a Microsoft Excel spreadsheet for data analysis. The traditional Borg scale (ratings 6 to 20) was used to assess perceived exertion near the end of each stage during the MXT and LTR-A and in 5-minute intervals during LTR-B.

Testing procedures

Maximal exercise test (MXT): Maximal exercise testing was conducted on a Schwinn Airdyne Cycle Ergometer. This air-braked combined arm/leg cycle ergometer was used because exercise on the LTR also involves both simultaneous arm and leg movements. To provide appropriate workloads for subjects with varying work capacities, 3 different continuous, incremental testing protocols were used. Subjects sat quietly on the cycle ergometer for at least 5 minutes during test preparations before collection of resting data for two minutes. Subjects then started exercise at a warm-up workload of 15, 25, or 40 watts. This work load was increased by 10, 15, or 20 watts every minute, depending on the respective protocol. The protocol, which varied in workload and increments, was selected after determining the apparent fitness of the individual based on an informal activity history. Tests were terminated when subjects reached volitional fatigue, defined as an inability to maintain the prescribed workload/cadence in spite of standard, enthusiastic encouragement by the testing staff.

The maximal oxygen uptake values were used to assign subjects to one of 3 fitness categories (low, medium, or high) based on percentile values and categories published in *ACSM's Guidelines for Exercise Testing and Prescription*.⁵ The lowest VO_2 values recorded over any continuous 60 seconds during the rest period were considered to be the resting values (VO_{2rest}). VO_{2R} was calculated from the

difference between VO_{2rest} and VO_{2max} .²⁵

LTR-A: This submaximal, progressive exercise test was conducted on a LTR of appropriate size as described above. The roll was placed on a carpeted floor and supported by a wall on one end. The subject sat on the highest portion of the opposite end. One examiner stood next to the subject to provide support for the expired gas collection tubing and to assist the subject in case of loss of balance (Figure 1). Another examiner monitored the subjects' metabolic and heart rate values, as well as the overall condition of the subject. The test was to be terminated prematurely if one of the following criteria occurred: (1) oxygen uptake in excess of 85% of VO_{2max} , (2) heart rate in excess of 90% of maximal heart rate, (3) musculoskeletal complaints, (4) abnormal signs or symptoms, (5) excessive local or general fatigue, or (6) request of the subject. The protocol consisted of 4 consecutive 5-minute stages of continuous exercise at increasing intensity levels followed by a 5-minute cool-down period. Exercise intensity was modified by increasing the height of the bounce and by incorporating additional muscle action through leg kicks and arm swings. The 4 levels of exercise intensity were defined as described below:

- LEVEL 1:** light bounce (without loss of contact with the ball surface)
- LEVEL 2:** vigorous bounce to the point of lift-off (loss of contact with the ball surface)
- LEVEL 3:** vigorous bounce and arm swings (see Figure 1)
- LEVEL 4:** vigorous bounce with simultaneous arm swings and leg kicks

These specific exercise activities performed during the individual stages of LTR-A were adapted from exercises presented in a commercially available exercise video and the book, *Swissball Applications for Orthopedics and Sports Medicine* by Posner-Mayer.^{19,20} Oxygen uptake and exercise heart rate were continuously monitored during the test and a rating of perceived exertion was obtained during the last minute of each stage of exercise. In order to confirm the assumption that subjects achieved steady state metabolic rate, exercise heart rates of min 4 and min 5 had to be within 5 bpm.⁵ If this requirement was not met, the stage was to be prolonged by an additional minute until steady state was achieved or terminated if exercise heart rate exceeded 90% of maximal heart rate as noted above. The means of the heart rate and oxygen consumption measurements of the last two minutes of each (steady state) phase were used for data analyses.

LTR-B: This submaximal exercise test on the LTR consisted of a 5-minute low intensity warm-up (Level I), 20 minutes of continuous exercise at an 'aerobic training intensity' and a 5-minute cool-down period (Level I) thus simulating a general aerobic training session. Based on the results of LTR-A, the exercise level that resulted in an energy expenditure of at least 65% of VO_{2max} by the end of the 5-minute period was assigned for the 20-minute exercise period. This level was adjusted during the test if necessary

Figure 1. Subject exercising at Level 4 on large therapeutic roll.

For this primarily descriptive study, individual values, group means of subjects in the same fitness category (high, medium, and low) as well as overall means of percent VO_2R and HR_{max} during LTR-A and LTR-B were compared to ACSM recommended ranges of aerobic exercise intensity. For the reliability pilot study the intraclass correlation coefficients (ICC 2,1) and 95% confidence intervals (CI) of 5 repeated measures of VO_2 , HR, and bounce cadence obtained during 5 repetitions of protocol LTR-A were calculated (SPSS version 15.0 for Windows).²⁶ Values below ICC 0.60 were interpreted as poor reliability and $\text{ICC} \geq 0.80$ reflected high reliability.²⁷

RESULTS

LTR Reliability Study

The ICC scores and 95% confidence intervals calculated from pilot data of 4 subjects who each completed 5 repetitions of the LTR-A test protocol are presented in Table 1. The reliability generally appeared to be good, with the exception of the reliability of the VO_2 measurements at Stage 1 (light bounce). Many of the confidence intervals were wide, which might be attributable to the small sample size.

Maximal Exercise Test

Maximal exercise data for all subjects are presented in Table 2. All subjects met all 3 of the following criteria for the attainment of $\text{VO}_{2\text{max}}$: (1) plateau of oxygen uptake, (2) $\text{RER} \geq 1.1$ and (3) maximal $\text{HR} \geq 90\%$ of age-predicted maximum (APMHR).²⁸

Overall mean $\text{VO}_{2\text{max}}$ was $43.6 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ and overall mean HR_{max} was 190 bpm (102% of APMHR). The mean of the RPE ratings during the last stage of the test was 18 (range 16-19 on 6-20 Borg scale).²⁹ Based on the achieved $\text{VO}_{2\text{max}}$, gender, and age, subjects were assigned to one of 3 fitness categories (high, medium, low). Subjects were assigned to these fitness categories based on percentile values for maximal aerobic power and fitness categories published by the ACSM.⁵ Individuals in the 95-99 percentiles (superior) were assigned to the high fitness (HF) category ($n=5$), individuals in the 40-94 percentiles (fair – good - excellent) were assigned to the medium fitness (MF) category ($n=4$) and individuals in the 1-39 percentiles (very poor – poor) were assigned to the low fitness (LF) category ($n=5$). Mean values of $\text{VO}_{2\text{max}}$ of the HF, MF, and LF groups were 55.7, 45.0, and $30.5 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$, respectively. Gender and age

to maintain an ‘appropriate exercise intensity’ that was defined as $> 40\% \text{VO}_2\text{R}$ (lower threshold for ‘moderate intensity’ exercise) and less than $85\% \text{HR}_{\text{max}}$ (upper limit of ‘submaximal’ exercise based on ACSM guidelines) and within a range of a rating of perceived exertion of 12-15.⁵ The same criteria for premature test termination were used as listed above for LTR-A. Oxygen uptake and exercise heart rate were continuously monitored during the test and a rating of perceived exertion was obtained every fifth minute throughout the test.

Data Analysis

Table 1. Reliability of VO_2 , HR, and Bounce Cadence During LTR Exercise

Stage	ICC(2,1) (95% Confidence Interval)		
	VO_2	HR	Cadence
1	0.55 (0.07, 0.95)	0.74 (0.34, 0.98)	0.92 (0.72, 0.99)
2	0.72 (0.29, 0.98)	0.90 (0.64, 0.99)	0.87 (0.57, 0.99)
3	0.90 (0.66, 0.99)	0.92 (0.71, 0.99)	0.83 (0.50, 0.99)
4	0.96 (0.83, 1.00)	0.94 (0.77, 1.00)	0.83 (0.52, 0.99)

Abbreviations: VO_2 , oxygen consumption; HR, heart rate; LTR, large therapeutic roll; ICC, intraclass correlation coefficient

Table 2. Subject Physical Characteristics and Maximal Exercise Values (SD)

High-Fit Subjects	Gender	Age	Weight (kg)	Height (cm)	VO _{2rest} (ml/kg/min)	VO _{2max} (ml/kg/min)	HR _{max} (bpm)	Fitness Category*
S1	M	40	66.0	182.9	3.8	56.7	196	superior (99)
S2	F	25	56.3	164.0	3.8	57.5	185	superior (99)
S3	M	29	65.9	177.8	3.6	57.8	190	superior (97)
S4	F	19	56.0	162.6	3.7	49.7	195	superior (95)
S5	M	26	78.0	173.0	3.8	56.7	187	superior (95)
Mean-HF	2F/3M	27.8(7.7)	64.4(9.0)	172.1(8.7)	3.7(0.1)	55.7(3.4)	191(4.8)	high
Medium-Fit Subjects								
S6	F	29	63.0	174.0	3.6	47.5	190	excellent (90)
S7	F	22	51.0	168.0	3.7	47.7	188	excellent (90)
S8	F	25	55.0	165.1	3.3	40.7	188	good (65)
S9	M	24	85.0	175.0	3.7	44.2	194	fair (51)
Mean-MF	3F/1M	25.0(2.9)	63.5(15.2)	170.5(4.8)	3.6(0.2)	45.0(3.3)	190(2.8)	medium
Low-Fit Subjects								
S10	F	39	58.0	176.5	3.8	33.4	172	poor (39)
S11	F	25	67.5	177.8	2.7	31.1	178	poor (19)
S12	M	28	108.5	180.3	3.5	32.5	206	very poor (5)
S13	F	26	82.5	172.7	3.1	25.5	186	very poor (4)
S14	M	25	92.0	193.0	4.3	29.9	203	very poor (3)
Mean-LF	3F/2M	28.6(5.9)	81.7(19.9)	180.1(7.7)	3.5(0.6)	30.5(3.1)	189(15.0)	low
Overall mean	8F/6M	27.3(5.8)	70.3(16.7)	174.5(8.1)	3.6(0.4)	43.6(11.5)	190(8.9)	

* fitness categories (percentile values for maximal aerobic power) based on ACSM's Guidelines for Exercise Testing and Prescription, 8th ed, 2010; Table 4.8, pp 84-9.

Abbreviations: SD, standard deviation; M, male; F, female; VO_{2rest}, resting oxygen consumption; VO_{2max}, maximal oxygen consumption; HR_{max}, maximal heart rate; HF, high fit; MF, medium fit; LF, low fit

distributions were similar in the three categories.

LTR-A

Exercise intensity expressed as percent oxygen uptake reserve (%VO_{2R}) during exercise at Level 1 through 4 is summarized by fitness category in Figure 2. The overall averages of %VO_{2R} during the last two minutes of exercise at Levels 1, 2, 3, and 4 were 11%, 34%, 45%, and 67%, respectively. All participants, regardless of their fitness level, were able to achieve at least 52% of their VO_{2R} while performing vigorous bouncing with combined arm swings and leg kicks during exercise at Level 4 on the LTR. The heart rate response to exercise at Level 1 through 4 is summarized by fitness category in Figure 3. Overall averages for percent HR_{max} during the last two minutes of exercise at Levels 1, 2, 3 and 4 were 45%, 61%, 70% and 83%, respectively. All participants, regardless of their fitness level, were able to achieve at least 71% of their HR_{max} while exercising at Level 4 intensity on the LTR. Three subjects in the LF category exceeded 90% of their HR_{max} after one to two minutes of exercise at Level 4 intensity, which resulted in test termination by the investigators as required by study protocol. For these 3 individuals, exercise data of the last

two minutes of exercise before test termination of LTR-A were substituted for Level 4 data. Ratings of perceived exertion to exercise at Level 1 through 4 are presented in Figure 4. Mean RPE ratings of all subjects were 8.6 at Level 1, 11.1 at Level 2, 12.6 at Level 3, and 14.1 at Level 4. The RPE ratings of subjects in the HF group were consistently lower than ratings of subjects in the LF and MF category.

LTR-B

Minute by minute averages of %VO_{2R} throughout LTR-B are summarized by fitness category in Figure 5. The overall mean percent of all individuals during the 20-minute continuous exercise period was 56% of VO_{2R}. The average exercise intensities ranged from 51%VO_{2R} to 64% VO_{2R} between subjects (Table 3). Means for individuals in the LF, MF, and HF categories were 55%, 60%, and 54%VO_{2R}, respectively. The lowest mean oxygen uptake was 57% of VO_{2max} (51%VO_{2R}), which was measured in a subject in the HF category. Minute by minute averages of percent HR_{max} throughout LTR-B are summarized by fitness category in Figure 6. Overall mean percent HR_{max} of all subjects during the 20-minute continuous exercise period was 78%. Average exercise intensities were similar between fitness

Figure 2. LTR-A - %VO₂R by intensity level & fitness category.

Abbreviation: VO₂R, oxygen uptake reserve

Figure 5. LTR-B - %VO₂R by fitness category.

Abbreviation: VO₂R, oxygen uptake reserve

Figure 3. LTR-A - %HR_{max} by intensity level & fitness category.

Abbreviation: %HR_{max}, percent maximal heart rate

Figure 6. LTR-B - %HR_{max} by fitness category.

Abbreviation: %HR_{max}, percent maximal heart rate

Figure 4. LTR-A - RPE by intensity level & fitness category.

Abbreviation: RPE, rating of perceived exertion

Figure 7. LTR-B - RPE by fitness category.

Abbreviation: RPE, rating of perceived exertion

categories (LF 78%, MF 79%, and HF 77% of HR_{max}). The lowest 20-minute average percent HR_{max} was recorded on a LF subject and was 72% HR_{max}. Average ratings of perceived exertion during the 20-minute continuous exercise period are presented in Figure 7 in 5-minute intervals. Overall mean RPE of all subjects during the 20-minute continuous exercise period was 13.2 with a range of individual ratings from 11 to 17.

All participants were able to complete the entire

exercise duration of LTR-B while maintaining an appropriate training intensity. All HF and MF individuals exercised at Level 4 during the entire 20-minute exercise period. Three of the 5 individuals in the LF category exercised at Level 3 because they reached and maintained appropriate training intensities when bouncing vigorously on the roll while performing alternating arm swings. The other two LF subjects alternated between Level 3 and Level 4 in order to maintain appropriate exercise intensities. One

Table 3. Average Exercise Intensity (%VO₂R and %HR_{max}) During the 20 Minute Training Phase of LTR-B (standard deviation)

High Fit Subjects	Gender	Age	VO _{2max} (ml/kg/min)	HR _{max} (bpm)	%VO ₂ R	%HR _{max}
S1	M	40	56.7	196	51	75
S2	F	25	57.5	185	59	77
S3	M	29	57.8	190	52	76
S4	F	19	49.7	195	54	76
S5	M	26	56.7	187	56	80
Mean-HF	2F/3M	27.8(7.7)	55.7(3.4)	191(4.8)	54(3.2)	77(1.9)
Medium-Fit Subjects						
S6	F	29	47.5	190	63	82
S7	F	22	47.7	188	62	82
S8	F	25	40.7	188	56	77
S9	M	24	44.2	194	59	76
Mean-MF	3F/1M	25.0(2.9)	45.0(3.3)	190(2.8)	60(3.2)	79(3.2)
Low-Fit Subjects						
S10	F	39	33.4	172	57	72
S11	F	25	31.1	178	60	82
S12	M	28	32.5	206	56	79
S13	F	26	25.5	186	51	74
S14	M	25	29.9	203	52	83
Mean-LF	3F/2M	28.6(5.9)	30.5(3.1)	189(15.0)	55(3.7)	78(4.8)
Overall mean	8F/6M	27.3(5.8)	43.6(11.5)	190(8.9)	56(4.0)	78(3.4)

Abbreviations: M, male; F, female; VO_{2max}, maximal oxygen consumption; %VO₂R, percent of oxygen uptake reserve; HR_{max}, maximal heart rate; %HR_{max}, percent of maximal heart rate; HF, high fit; MF, medium fit; LF, low fit

LF individual exercised at Level 3 for 12 minutes and then alternated between Level 3 and Level 4 for the remaining 8 minutes to ensure an appropriate training intensity. The other LF individual exercised at Level 4 for the initial 9 minutes and then alternated between Level 4 and Level 3 for the remaining 11 minutes to avoid exceeding an RPE rating of 15. Exercise sessions on the LTR were tolerated well by all participants. Adverse events included delayed onset muscle soreness in proximal lower extremity muscles and shoulder muscles in some of the less conditioned subjects. In addition, a few persons who wore loose fitting shorts experienced some skin chafing in the upper posterior and medial thigh and lower gluteal area due to the repetitive upward shearing of the fabric caused by the high friction of the vinyl surface.

DISCUSSION

Our study is the first to report the cardiorespiratory response to endurance exercise on the LTR in a group of young healthy adults. We found that our LF and MF groups could maintain greater than the recommended minimal training threshold (see Table 3) during a simulated 20-minute training session. In contrast, the HF group did not appear to attain the recommended training intensity to

increase VO_{2max} in trained athletes. However, the training intensity attained using the LTR, if combined with the appropriate frequency and duration, would be sufficient to maintain overall fitness and health in the HF group. Lastly, these training intensities using a LTR could be attained reliably over repeat sessions with the exception of the lowest training intensity (Stage 1 – light bounce).

The threshold intensity of exercise required to improve cardiorespiratory fitness depends on the initial state of fitness of an individual. Swain and Franklin⁶ analyzed data from 18 aerobic training studies and concluded that for persons with a baseline VO_{2max} of less than 40 mL·kg⁻¹·min⁻¹ an exercise intensity of at least 30% VO₂R provides sufficient stimulus to improve aerobic capacity. Our subjects in the LF group fall into this category. During continuous exercise for 20 minutes (excluding 5-minute warm-up and cool-down), they maintained an average exercise intensity of 55.3% VO₂R (range 51.3-59.9%VO₂R) that greatly exceeded the recommended minimal training threshold (see Table 3). In regard to 'higher fit subjects' (baseline VO_{2max} of 40-51 mL·kg⁻¹·min⁻¹), Swain and Franklin's study⁶ determined a minimal training threshold of 45% VO₂R. The subjects in the MF group of our study fall into this category. During continuous exercise for 20 minutes (excluding

5-minute warm-up and cool-down), they maintained an average exercise intensity of 60.3% $\text{VO}_{2\text{R}}$ (range 56.3-63.3% $\text{VO}_{2\text{R}}$) also well above the recommended minimal training threshold (see Table 3). A comprehensive review of exercise training studies of trained distance runners by Midgley et al²⁸ confirms that the threshold intensity to improve maximal oxygen uptake is highly dependent on the initial $\text{VO}_{2\text{max}}$ and suggests a training intensity of 70% to 80% $\text{VO}_{2\text{max}}$ (equivalent to approximately 68-79% $\text{VO}_{2\text{R}}$) for trained runners and 'near maximal' training intensities for elite runners to elicit further improvements of aerobic capacity. Subjects in the HF group maintained an average exercise intensity of 54.2% $\text{VO}_{2\text{R}}$ (range 50.8-58.6% $\text{VO}_{2\text{R}}$) during continuous exercise for 20 minutes (excluding 5 minute warm-up and cool-down) that is significantly below the recommended threshold intensity to increase $\text{VO}_{2\text{max}}$ in these trained athletes. However, while not sufficient to elicit further increases in maximal aerobic capacity in these individuals, training at this intensity for adequate duration and frequency may result in sufficient total energy expenditure to maintain overall fitness and health.

Our findings suggest that healthy, young to middle-aged adults, regardless of fitness level, are able to maintain exercise at a moderate intensity level for at least 20 minutes while exercising on the LTR. Even in highly trained individuals, combining rhythmic upper and lower extremity movements with a vigorous bouncing action elicited an average exercise heart rate over a 20-minute session of at least 75% of HR_{max} . Exercise at that level, especially if maintained for a longer duration, should provide a conditioning workout for these individuals. The same type of LTR exercise evoked maximal cardiorespiratory stress in LF individuals as suggested by an exercise heart rate in excess of 90% after one to two minutes of exercise at Level 4 of LTR-A, when exercise of these individuals was terminated before a steady state condition was achieved. Aerobic conditioning exercise on the LTR may therefore be most appropriate and appealing for less fit individuals that are able to maintain an appropriate exercise intensity while varying activity routines, thus avoiding monotony.

Limitations of this study regarding external validity include the recruitment of a convenience sample and the small sample size with only 4 to 5 subjects in each fitness category. The average age of this relatively young cohort was 27.3 years (range 19-40 years). Results of this study may not be applicable to older individuals who may have less agility and balance. Further limitations regarding the reproducibility of these tests include the variability of ball characteristics and the difficulty to accurately standardize and monitor exercise parameters such as bounce height, bounce cadence, and amplitude of excursions of arm and leg movements. As a result, it is impossible to exactly replicate testing across and within subjects and across laboratories as compared to testing conducted on calibrated cycle ergometers or treadmills. Furthermore, due to the complexity of this activity, significant variability in mechanical efficiency between subjects may exist. However in spite of these difficulties, our study suggests

good reliability of key exercise variables within subjects.

POTENTIAL CLINICAL APPLICATIONS AND PRECAUTIONS

Exercise on the LTR requires a high level of coordination and provides a constant challenge to balance. Therefore, one may hypothesize that conditioning training on the LTR will not only increase cardiorespiratory fitness and provide the numerous health benefits associated with such physical activity, but may improve coordination and balance as well. This mode of exercise may be very beneficial for individuals with balance impairments such as neurological disorders or the elderly. Karthikbabu et al¹³ demonstrated significant improvements in functional balance measures in persons with acute stroke after 12 one-hour training sessions of trunk exercises on a therapeutic ball. Further studies need to examine if persons with balance deficits are able to perform aerobic exercise routines effectively on the LTR and if such training improves functional mobility and balance. Precautionary measures may preclude or require using a modified approach in persons with balance deficits, impaired cognition, or those who have musculoskeletal problems aggravated by the positioning required or bouncing induced by the LTR cardiorespiratory training protocol, such as musculoskeletal disorders of the lower extremity, back, neck, and shoulder. Lastly, prolonged exercise on the LTR may result in skin irritation or chafing from clothing due to the high friction of the vinyl surface. This is most likely experienced when loose fitting shorts are worn, but can be avoided by using tight bicycle shorts or tight, long leg wear.

CONCLUSIONS

Large therapeutic rolls are appropriate aerobic fitness tools for healthy, adult persons of all fitness levels. All participants in this study, including those with superior aerobic capacity, were able to achieve and maintain at least moderate-intensity exercise as recommended by the ACSM for cardiorespiratory training to maintain health and fitness. The authors suggest that therapeutic balls and rolls offer a fun, creative, and unique mode of aerobic training that not only trains the cardiovascular system, but challenges other systems such as proprioception and balance as well.

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