Original Research

Stability Ball Sitting Elevates Peak Arm Ergometry Oxygen Consumption and Heart Rate

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ABSTRACT

International Journal of Exercise Science 5(4) : 360-366, 2012. This study compared sitting on a stability ball (B) to sitting on a chair (C) during arm ergometry to determine the impact on peak VO_2, peak heart rate (HR), and exercise intensity prescription. Open-circuit spirometer, blood pressure, and HR were monitored during rest and continuous graded exercise test to exhaustion using an arm ergometer. Twenty-seven apparently healthy adults exercised twice, once at B and the other trial C (order randomized), with 60 minutes of rest between trials. ANOVA for repeated measures ($\alpha < 0.05$) and paired *t* testing using Holm's-sequential Bonferroni were used to analyze results for 30 W, 45 W, Penultimate, and Peak stages of exercise. VO_2 was significantly higher (8% to 12%, $P < 0.001$) for all stages of exercise for B compared to C. HR was significantly higher ($P < 0.001$) only at the Penultimate and Peak levels (3% and 2%, respectively) for B compared to C; all other sub-maximal HRs were not significantly different. There were no significant main effects or interactions ($P \geq 0.138$) when VO_2 and HR were expressed as percentage of maximum. Compared to chair sitting, the stability ball has a greater absolute metabolic response with little impact on HR. Prescribing exercise with absolute MET levels should consider this; however, intensity as a percentage of maximum may not be affected by the stability ball.

KEY WORDS: Cardiovascular, aerobic arm exercise, Swiss ball, VO_2

INTRODUCTION

Stability ball use has been investigated for its potential to increase muscular activity during core muscle exercises (2,10,12) and as a replacement for chair sitting (7,11) in an effort to aid in preventing or attenuating low back pain. However, until recently there have been no reports on the impact of using the stability ball during aerobic exercise. This is understandable since using the stability ball during most aerobic activities seems unpractical. But arm ergometry generally involves sitting on a chair which can be easily replaced by a stability ball. Arm ergometry has been used for upper body aerobic training (3,4,5) in fitness centers, cardiac rehabilitation, and spinal cord injury rehabilitation.

One of the limiting features of arm ergometry is that despite the higher VO_2 at a given power output when compared to leg exercise (5,8) the potential total energy expenditure is expected to be lower than leg exercise because of the arm's lower peak VO_2 (5,8). This limits arm exercise as a means to expend energy for body fat loss programs. The addition of a stability ball could elevate VO_2 and thus energy expenditure. This laboratory has reported that stability ball sitting elevates sub-maximal VO_2 10% to 16% (9). Another concern is the impact the stability ball could have on heart rate during arm exercise. It has been shown that arm ergometry has higher heart rates at a given power output than leg exercise (5,8) and the addition of a stability ball might be expected to increase heart rates further. However, our laboratory has demonstrated that the stability ball may not impact heart rates during sub-maximal arm ergometry (9). Maximal or peak levels are important for exercise prescription and to evaluate exercise training programs. The only known study to report on the impact of stability ball sitting during arm ergometry was limited to sub-maximal exercise (9).

The purpose of this study was to determine if sitting on a stability ball results in greater cardiorespiratory responses to continuous graded arm exercise to exhaustion and look at the potential impact on exercise prescription concerns.

METHODS

Participants

Twenty-seven apparently healthy female and male adult participants were recruited after the University Institutional Review Board approval. Criteria for participation included absence of cardiac, pulmonary, and metabolic disease, 18 to 40 years of age, and be at least moderately active (3 days/week of walking 30 minutes e.g.).

Protocol

When a participant first entered the laboratory the informed consent was obtained and the participant had to answer no to all questions on the Physical Activity Readiness Questionnaire (1) in order to continue on that day for exercise testing. The participant then practiced sitting on the ball, cranking at 50 revolutions per minute (rpm), and was familiarized with the blood pressure procedure. Sitting heights—right shoulder height to floor—on the chair and ball were measured using a stadiometer to ensure sitting heights were about equal; a wooden platform was placed under the lower sitting mode to adjust the sitting height to be within two centimeters of the other. Body mass was also measured using a balance scale (Detecto, Webb, MO).

Following the initial procedures, the participant then underwent two graded exercise tests to exhaustion: one on the chair (44 cm seat height unless adjusted) and one on a stability ball (75 cm diameter) with a one hour rest between. This time frame was chosen to replicate our earlier study's design for possible comparisons (9). The participants were instructed to position the chair (without back support) or ball and their feet in ways that were most comfortable to them. The two tests started with four minutes of rest then began continuous graded exercise at 15 W or 30 W (smaller individuals with little upper body exercise experience started at the 15 W) that increased 15 W every four minutes until the participant was unable to maintain the 50 rpm. Individuals were continuously encouraged to maintain the 50 rpm throughout the test. When an individual could no longer get back to 50 rpm or sustain it for 10 seconds or more after encouragement, the test was terminated. We made sure that all participants had 30 W and 45 W stages so that we could make some comparisons to our earlier study. Once the graded exercise test was terminated, the participants went into a two minute active recovery period (zero load at a self-paced rpm). Following this, 60 minutes of rest occurred between the two exercise tests. The participants read, did paper work, worked on their computers, etc. during the rest period. No food was taken and only water was ingested between tests. The order of sitting mode was randomized by the following: each participant was assigned an ID number. For odd numbered ones a coin was tossed to determine whether to start with the chair or stability ball, the subsequent even numbered participant was assigned to the other sitting mode.

An arm ergometer (Monark 818, Sweden) was used for the exercise test with the revolution rate goal set at 50 rpm. During the tests oxygen consumption (VO_2) was continuously measured by open-circuit spirometry (MAX-I, AEI Technologies, Naperville, IL). The MAX-I was calibrated using 4.00% CO_2 and 16.00% O_2 before each exercise session. Heart Rate (HR) was continuously recorded using a Polar monitor (Polar Electro Inc., Woodbury, NY) with the sensor connected to the MAX-I computer. Systolic (SBP) and Diastolic (DBP) blood pressures were measured on the left arm after three minutes of rest and after the third minute of each stage of exercise in order not to affect each stage's VO_2 and HR measurements. An aneroid sphygmomanometer and stethoscope were used to measure SBP and DBP with the following procedure: power output was reduced by half the wattage for that stage while the participant maintained the 50 rpm with the right arm and while the blood pressure was measured on the left arm.

Measurements at the 30 W, 45 W, Penultimate, and Peak stages were analyzed. The average VO_2 and HR from two and a half minutes to the third minute of rest and two and a half minutes to the third minute each stage of exercise were used for evaluations. VO_2 and HR were also expressed as a percentage of their peak levels. Peak VO_2 in $mL \cdot kg^{-1} \cdot min^{-1}$ was also calculated.

Statistical Analysis

A 2 (sitting mode) x 4 (Power Output) repeated measures ANOVA was used with significance set at $\alpha \leq 0.05$. If a significant main effect for sitting mode was found then paired *t* tests with Holm's Sequential Bonferroni procedure (6) was used for follow-up analyses. A paired *t* test was used to determine if there was a significant ($\alpha \leq 0.05$) difference between sitting modes for sitting height. SPSS version 11.5 was used for all statistical analyses. Our prior study indicated that η^2 would be greater than 0.2 for VO_2. Setting $\eta^2 = 0.2$, Power = 0.80, and $\alpha \leq 0.05$, an n = 20 would be needed for a repeated measures ANOVA (13).

RESULTS

Table 1 contains the participant characteristics. Each and every participant achieved the same peak power output for both sitting modes (Mean $\pm$ SD = 103 $\pm$ 29 W, also see Table 1). The average *absolute* difference between the stability ball and chair for time to exhaustion was 0.2

minutes; however, the average time to exhaustion was 18.0 ± 2.6 minutes on the ball and 17.9 ± 2.6 minutes on the chair and did not differ significantly ($P = 0.458$).

Table 1. Participant characteristics (Mean ± SD).

	n	Age (yrs)	Body Mass (kg)	Peak Power Output (W)
Females	13	21 ± 2	60.6 ± 7.2	84 ± 18
Males	14	22 ± 1	75.0 ± 5.5	121 ± 25

Table 2 contains the mean ± SD for VO_2 and HR for the two sitting modes during 30 W, 45 W, Penultimate, and Peak stages. ANOVA for repeated measures revealed significant main effects (sitting mode and power output, $P < 0.001$) and interaction ($P = 0.013$) for VO_2. Paired t tests with Holm's Sequential Bonferroni procedure demonstrated that VO_2 was significantly ($P < 0.001$) higher by 8% to 12% on the stability ball for all four stages of exercise. Average peak VO_2 was 30.5 ± 4.1 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$ on the stability ball and 27.6 ± 4.5 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$ on the chair. In addition, HR had significant power output and sitting mode main effects ($P < 0.001$ and $P = 0.003$, respectively) and non-significant interaction (P = 0.361). Paired t tests with Holm's Sequential Bonferroni procedure demonstrated that HR was significantly ($P < 0.001$) higher by 3% and 2% on the stability ball for the Penultimate and Peak stages, respectively but not significantly different for the 30 W ($P = 0.161$) and 45 W ($P = 0.097$). Table 3 expresses the VO_2 and HR results as a percentage of peak levels. As a percentage of peak, VO_2 had non-significant sitting mode main effect ($P = 0.394$) and interaction ($P = 0.138$). In addition, HR as a percentage of peak levels had no significant sitting mode main effect ($P = 0.589$) and interaction ($P = 0.538$).

Table 2. Impact of sitting mode on VO_2 and HR during arm ergometry (Mean±SD).

	VO_2 ($mL{\cdot}min^{-1}$)		HR ($b{\cdot}min^{-1}$)	
	Ball	Chair	Ball	Chair
30 W	743±115*	680±108	106±13	104±16
45 W	971±121*	869±100	121±17	118±19
Penult	1609±319*	869±100	161±14*	156±15
Peak	2087±475*	1893±449	178±10*	174±10

* Paired t test $P < 0.001$ between Ball and Chair

Table 3. VO_2 and HR as a percentage of peak values (Mean±SD).

	VO_2 (%)		HR (%)	
	Ball	Chair	Ball	Chair
30 W	40±8	37±8	60±6	60±7
45 W	49±10	48±11	68±8	67±9
Penult	78±7	80±7	90±4	89±5

Table 4 contains the mean ± SD for SBP and DBP for the two sitting modes during 30 W, 45 W, Penultimate, and Peak stages. Regarding SBP, there was a significant ($P < 0.001$) power output main effect. Sitting mode main effect and interaction were not significant ($P = 0.072$ and $P = 0.076$, respectively). Regarding DBP, there was a significant ($P < 0.011$) power output main effect. Sitting mode main effect and interaction were not significant ($P = 0.294$ and $P = 0.618$, respectively).

Table 4. Sitting mode impact on blood pressure during arm ergometry (Mean±SD).

	SBP (mm Hg)		DBP (mm Hg)	
	Ball	Chair	Ball	Chair
30 W	121±11	114±26	76±10	79±10
45 W	131±12	127±11	80±10	80±10
Penult	146±12	146±14	82±13	83±12
Peak	149±11	150±13	84±13	86±12

Though HR and SBP were little or non-significantly affected by the stability ball, their double product had significant sitting mode ($P = .009$) and power output ($P < .001$) main effects and no significant interaction ($P = .881$). The stability balls double products were 4 to 8% higher than the chair's.

DISCUSSION

This is the first study to investigate cardiorespiratory responses during peak arm ergometry while sitting on a stability ball. Compared to chair sitting, sitting on the stability ball resulted in significantly higher VO_2 across all four stages and significantly higher HR at the Penultimate and Peak stages. There are a few differences between our earlier study (9) and this study: this study controlled for seat height, its practice session was done on the same day as testing, and its participants exercised to fatigue. Even with these differences, the impact of sitting on the stability ball on VO_2 (increase compared to chair) was similar: 13% and 10% in prior study and 9% and 12% in this study at 30 W and 45 W, respectively. It appears that this study confirms our earlier findings on sub-maximum VO_2 and demonstrates that the effect continues to peak VO_2. Though peak VO_2 was higher on the stability ball, peak time to exhaustion remained the same. This and the higher VO_2 with all stages may indicate greater muscle recruitment with the stability ball in non-arm muscles. Our earlier work had significantly higher EMG activity in the rectus femoris and external oblique muscles with the stability ball (9). Leg and trunk muscles were probably recruited to stabilize the trunk and lower body.

The HR results in this study also were similar to our prior study: non-significant differences between the stability ball and chair at the 30 W and 45 W stages. However, we did find significantly higher HRs at the Penultimate and Peak stages for stability ball sitting but they were relatively small (3% and 2%, respectively) compared to the VO_2 increases (8% and 10%, respectively). These results confirm our earlier study's finding but indicate that it does not extend to near peak and peak HR but again the effect is small. The small effect is not surprising given the impact of an already increased heart rate brought about by upper body exercise (5,8) and the relatively small potential increase in HR compared to VO_2 increases (75 to 180 b/min compare to 250 mL/min to 2000 mL/min e.g.). As discussed in our prior study (9), the HR results indicate that stroke volume, oxygen content difference or both deliver(s) the extra oxygen with stability ball sitting. Even though the Penultimate and Peak stages' HRs were higher in this study, they were higher by a relatively smaller amount compared to the increased VO_2 at those stages and again indicate other cardiac/hematological parameters contributing to the extra oxygen delivery.

There were no significant differences between sitting modes for blood pressure and confirms our earlier findings. If other studies continue to demonstrate no significant effects of the stability ball (compared to chair) on SBP, then this may indicate that one can elevate the metabolic response to arm ergometry without perhaps elevating the cardiac oxygen demands. However, we did find the double product to be 4-8% higher on the stability ball compared to the chair.

Our earlier study (9) discussed implications of using the stability ball during arm ergometry for weight loss programs (higher stability ball VO_2 leads to higher energy expenditure) and cardiac rehabilitation programs (higher submaximal VO_2 without higher HR and SBP). In addition, we discussed that the higher VO_2 indicated higher MET levels at a given power output and needed to be considered if intensity is prescribed in absolute MET levels. The current study does not change that implication for absolute MET levels, however, since the relationship between percentage of peak VO_2 and percentage of peak HR does not appear to differ between the stability ball and chair sitting (Table 3), this indicates that an individual's exercise prescription based on percentage of peak VO_2 or HR is not different for a given wattage between the stability ball and chair sitting modes.

This study limited the participants to apparently healthy young adults and used the same diameter ball for every participant. It would be of interest to study older participants and individuals in cardiac rehabilitation to determine if they have the same VO_2, HR, and blood pressure responses as our participants. In addition, it would be interesting to determine if the stability ball results in any training benefits over the chair. We limited our reporting of submaximal data to 30 W and 45 W to compare to our earlier work, expanding this research to incorporate a greater number of power output levels is warranted. We did limit the rest period to only one hour to approximate the conditions of our earlier work. However, this could attenuate any differences if recovery was not sufficient. We have not explored the impact of stability ball size or pressure or compare other types of sitting furniture with arm ergometry. Within these limitations, this study's results indicate that for apparently healthy young male and female adults, sitting on the stability ball during arm ergometry significantly elevates oxygen consumption without significantly affecting sub-maximal cardiovascular parameters but has a relatively smaller increase in HRs at high intensity. In addition, it appears that exercise prescription based on % peak VO_2 or % peak HR from arm ergometry chair sitting can still be used when replacing the chair with a stability ball.

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REFERENCES

1. American College of Sports Medicine. ACSM's Guidelines for Exercise Testing and Prescription. 8th ed. Philadelphia (PA), Baltimore (MD): Wolters Kluwer; Lippincott, Williams & Wilkins, p. 20, 2010.

2. Duncan M. Muscle activity of the upper and lower rectus abdominis during exercises performed on and off a Swiss ball. J Body Move Ther 13:364-367, 2009.

3. Franklin BA. Exercise testing, training and arm ergometry. Sports Medicine 2:100-119, 1985.

4. Franklin BA. Aerobic Exercise Training Programs for the Upper Body. Med Sci Sports Exerc 21(5, Suppl): S141-S148, 1989.

5. Franklin BA, Vander L, Wrisley D, Rubenfire M. Aerobic Requirements of Arm Ergometry: Implications for Exercise Testing and Training. Phys Sports Med 11(10): 81-90, 1983.

6. Green SB, Salkind NJ. Using SPSS for Windows and Macintosh: analyzing and Understanding Data. 3rd ed. Upper Saddle River (NJ): Prentice Hall, p. 231, 2003.

7. Gregory DE, Dunk NM, Callaghan JP. Stability Ball Versus Office Chair: Comparison of Muscle Activation and Lumbar Spine Posture During Prolonged Sitting. Hum Factors 48(1): 142-153, 2006.

8. Keteyian SJ, Marks CRC, Levine AB, Kataoka T, Fedel F, Levine TB. Cardiovascular Responses to Submaximal Arm and Leg Exercise in Cardiac Transplant Patients. Med Sci Sports Exerc 26(4): 420-424, 1994.

9. Marks CRC, Hylland KE, Terrell J. Stability Ball Sitting versus Chair Sitting During Sub-maximal Arm Ergometry. Int J Exerc Sci 5(1): 16-25, 2012.

10. Marshall PW, Murphy BA. Core Stability Exercise On and Off a Swiss Ball. Arch Phys Med Rehabil 86: 242-249, 2005.

11. McGill SM, Kavcic NS, Harvey E. Sitting on a chair or an exercise ball: Various perspectives to guide decision making. Clin Biomech 21: 353-360, 2006.

12. Sternlicht E, Rugg S, Fujii LL, Tomomitsu KF, Seki MM. Electromyographic Comparison of a Stability Ball Crunch With a Traditional Crunch. J Strength Cond Res 21(2): 506-509, 2007.

13. Warner, RM. Applied Statistics: From Bivariate Through Multivariate Techniques. Los Angeles (CA): Sage Publications, p. 917, 2008.