©Journal of Sports Science and Medicine (2004) **3**, 254-260
http://www.jssm.org

Research article

COMPARISON OF VO_2 PEAK DURING TREADMILL AND CYCLE ERGOMETRY IN SEVERELY OVERWEIGHT YOUTH

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Received: 21 July 2004 / Accepted: 22 November 2004 / Published (online): 01 December 2004

ABSTRACT
The purpose of this study was to compare peak cardiorespiratory parameters during treadmill and cycle ergometry in severely overweight youth. Twenty-one participants from the Committed to Kids Pediatric Weight Management program at the Louisiana State University Health Sciences Center volunteered. Participants completed peak treadmill and cycle ergometer tests on separate days. In order to examine reliability, six subjects completed a second treadmill test and seven subjects a second cycle test. Physical characteristics included the following: Age (yrs) 12.5 ± 2.8; Body weight (BW) (kg) 78.5 ± 27.0, Height (m) 1.56 ± 0.13; and % fat 42.8 ± 7.5. No statistical significant differences ($p \le 0.05$) were found between treadmill and cycle peak tests. Treadmill VO_2 peak ($l{\cdot}min^{-1}$) averaged 1.57 ± 0.40 and cycle 1.46 ± 0.30 and VO_2 peak relative to BW 21.5 ± 4.1 and 20.3 ± 5.5 for treadmill and cycle ergometry, respectively. Therefore treadmill values were 7.0% and 5.6% higher than cycle values. In normal weight or children and adolescents at risk for overweight, treadmill values typically average from 7 to 12% higher than cycle values. Reliability of VO_2 peak as indicated by intraclass correlation coefficients ranged from 0.70 to 0.96 for a single or repeated tests. Intra individual variability averaged 0.5% for VO_2 peak ($l{\cdot}min^{-1}$) during treadmill ergometry and 5.7% for cycle ergometry. Also, standard errors of measurement were low (40 to 90 ml min or 1.0 to 1.7 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$) for the peak treadmill or cycle tests. In summary, our data suggest that both treadmill and cycle ergometry provide reliable methods for determining VO_2 peak in overweight youth.

KEY WORDS: VO_2 peak, severely overweight youth, treadmill and cycle ergometry.

INTRODUCTION

Oxygen uptake peak (VO_2 peak) or VO_2 max indicates the functional capacity of cardiorespiratory function and is often considered as the benchmark indicator of cardiorespiratory fitness (McArdle et al., 1996). In addition to evaluating functional capacity in healthy and diseased individuals, VO_2 peak is used to prescribe endurance exercise and monitor physical training adaptations (Shephard, 1984). Exercise scientists have recently suggested minimal VO_2peak ($ml{\cdot}kg^{-1}{\cdot}min^{-1}$) values for health fitness (Cooper, 1968; Cureton et al., 1990). Based on Cooper's suggestion of a $VO_2max \ge 42$ $ml{\cdot}kg^{-1}{\cdot}min^{-1}$ in adult males as indicative of good health and functional capacity, a minimal VO_2peak of 42 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$ was recommended for boys aged 5 to 17 years and 40 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$ for girls who ranged in age from 5 to 9 years (Blair et al., 1989). A decrease of one unit per year was set for girls aged 10 to 14 years and thereafter, held constant at 35 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$ through age 17. Lower suggested values for young females were due to lower hemoglobin levels and higher sex specific fat values (Cureton et al., 1990). Children and adolescents with VO_2 peak values that fall below these minimal suggested values may be at increased risk for developing coronary artery disease and other hypokinetic diseases earlier in life. For example, Kwee and Wilmore (1991) found lower fit (VO_2peak) boys, aged 8 to 15 years, to be significantly fatter, exhibit higher resting blood pressure and have higher triglyceride levels than higher fit boys.

Typically, either the treadmill or cycle ergometer has been used for VO_2peak testing in either children or adults. Higher VO_2max values have been reported during maximal treadmill as compared to cycle ergometry. In a review article examining adults, Shephard (1984) reported an average difference of 9 % between ergometers with the treadmill yielding higher values in all 20 studies reviewed. Also, differences ranged from 1 to 18% across studies. In normal weight children, aged 8 to 14 years, VO_2 max averaged from 7 to 11% higher during treadmill as compared to cycle ergometry (Boileau et al., 1977; Turley et al., 1995; Duncan et al., 1996; Rivera-Brown 1998). Higher VO_2max values during treadmill ergometry have been attributed to a larger exercising muscle mass (Boileau et al., 1977).

Over the past 30 years, the preponderance of overweight youth has increased (Troiano et al., 1995). The increase, in part, has been attributed to a decline in physical activity among children and adolescents (McGinnis, 1992). Moreover, overweight children and adolescents are typically less physically active, in particular when physical activity was expressed relative to body weight, than non-overweight children and adolescents (Bar-Or, 1993). The U.S. Center for Disease Control (2004) defines BMI ($kg \cdot m^{-2}$) scores $\geq 85^{th}$ to $< 95^{th}$ percentile as at risk for overweight for children and youth. Also, BMI scores $\geq 95^{th}$ percentile is defined as overweight.

In order to evaluate peak cardiorespiratory function and accurately prescribe endurance exercise, VO_2peak, when available, should be assessed. In a review of the literature only one study was found that compared VO_2peak during treadmill to cycle ergometry in obese (mild) adolescents (Maffeis et al., 1994). Non-significant differences in VO_2peak expressed in absolute or relative to body weight units were found when treadmill was compared to cycle ergometry. Absolute VO_2peak ($l \cdot min^{-1}$) was 9.7% higher and relative VO_2peak ($ml \cdot kg^{-1} \cdot min^{-1}$) 12.9% higher during treadmill ergometry. Reliability coefficients of treadmill or cycle ergometer peak tests were not included. The purpose of the present study was to compare peak cardiorespiratory responses during treadmill and cycle ergometry in severely overweight youth, and to examine test-retest reliability and variability of VO_2peak.

METHODS

Subjects

Twenty-one severely overweight youth (19 females, 2 males) enrolled in the one year Committed to Kids Weight Management program at the Louisiana State University Health Sciences Center of New Orleans volunteered. We categorized the participants as severely overweight since the average BMI of the group was 32. This placed the group 4 units above the 97^{th} percentile for age and gender. Subsequent to participation the subjects and parent(s) were given full details of the study and informed consent was obtained. A Physician's scale was used to measure weight, a stadiometer to measure height and body composition was assessed via the skinfold method using the Slaughter et al. (1988) equations.

Procedures

The subjects were initially familiarized with the laboratory and practiced treadmill walking and leg cycling. Following laboratory habituation the subjects were randomly assigned to initially completing the treadmill or cycle ergometer test. All ergometer tests were separated by at least 48 hours and testing was scheduled for the late afternoon. The participants were instructed to refrain from strenuous physical activity on testing days and were instructed not to eat for at least 4 hours prior to testing. Seven subjects volunteered for a cycle ergometry retest and six for a treadmill retest.

A Sensormedics MMC-l was used to measure VO_2, carbon dioxide production (VCO_2), pulmonary ventilation (VE), temperature and barometric pressure. Prior to and following each test, the apparatus was calibrated against a standard commercial gas mixture. The participants used either a pediatric or adult mouthpiece that was attached to Hans Rudolph, model 2700 breathing valve. Heart rate was measured with a Polar Vantage XL heart rate monitor. Criteria for VO_2 peak was adopted after Rowland (1991) and included heart rate > 190 bpm or RER > 0.98.

Treadmill Test

A walking protocol was employed for treadmill testing as pilot work indicated that the participants were unable to maintain a running pace. A Quinton, model 18-60-1 treadmill was used for all testing. The subjects could comfortably walk at either 4.0 or 4.8 $km \cdot hr^{-1}$, consequently, 5 of the youth completed the test at 4.0 and 16 at 4.8 $km \cdot hr^{-1}$. A 5 minute warm-up period at 3.2 $km \cdot hr^{-1}$ was completed prior to the peak test. Throughout the peak test treadmill speed was held constant and elevation (grade) was increased by 2% every 2 minutes until volitional termination. Subjects were verbally encouraged to continue until exhaustion.

Cycle Test

The subjects completed a 5 minute warm-up at 25 W prior to maximal testing on a Monark, model 686 cycle ergometer. Pedal rate was held constant at 60 rpm throughout testing. The peak test began at unloaded cycling, 60 rpm for 2 minutes. Thereafter, workload increased by 29 W (0.5 kg) every 2 minutes until 118 W. From this point on, power output was increased by 15W (0.25 kg) until volitional termination or a drop in pedal rate of 5 rpm.

Statistical Analysis

An independent t-test test was used to compare peak responses of the initial treadmill and cycle ergometer tests. Intraclass correlation coefficients (R) were used to examine reliability with one-way ANOVA. In this analysis R_{xx}'= (MSs -MSe) / MSs for reliability of both trials and R = (MSs –MSe) / MSs + MSe) for an estimate of 1 trial (MSs = mean square of subjects; MSe = mean square of error). The error term was the subject x trial interaction (Baumgartner and Jackson, 1991). Standard errors of measurement were computed from the following equation:

$SEM=Sx\sqrt{1-xx^1}$

Intra individual variability was calculated consistent with the procedures of Turley et al. (1995). In this procedure the absolute individual difference between test 1 and test 2 was computed along with the percentage difference (absolute diff / M of test 1 & 2 x 100). Dependent t-tests were computed to compare cardiorespiratory variables from trial 1 to trial 2. The alpha level of significance was set at 5 %.

RESULTS

Physical characteristics of the participants are located in Table 1. As indicated, body fat averaged 42.8%, indicating a high level of adiposity. Moreover, all of the youth tested had BMI levels > 85^{th} percentile for age and gender with 18 exhibiting values > 95^{th} and 14 > 97^{th} percentile. Cardiorespiratory parameters during peak treadmill and cycle ergometry can be found in Table 2. The duration of the treadmill test averaged 10.7 minutes and 9.6 minutes for the cycle test. As noted, with the exception of RER, no significant differences occurred when treadmill was compared to cycle ergometry. Moreover, moderate to high correlations were found between treadmill and cycle tests. Figure 1 illustrates a scattterplot of treadmill and cycle ergometry VO_2peak (ml·kg^{-1}·min^{-1}). VO_2peak averaged 5.6% (ml·kg^{-1}·min^{-1}) or 7.0 % (l·min^{-1}) higher during peak treadmill exercise.

Reliability of peak VO_2 during treadmill and cycle ergometry can be found in Table 3. In general, with the exception of VO_2 peak relative to BW during cycle ergometry, the R values were very high (> 0.95). Standard errors of measurement were low as they ranged from 49 to 70 ml·min^{-1} or 0.7 to 1.4 ml·kg^{-1}·min^{-1}. Also, intra individual variability for the test-retest values ranged from 0.5 to 6.6 %.

Table 1. Physical characteristics of the participants (n = 21).

Variables	Mean (SD)
Age (yrs)	12.5 (2.8)
Body mass (kg)	78.5 (27)
Height (m)	1.56 (.13)
BMI (kg·m^{-2})	32.0 (7.8)
Body fat (%)	42.8 (7.5)
Fat mass (kg)	36.6 (17.8)
Fat free mass (kg)	45.9 (11.2)

DISCUSION

The primary purpose of the current study was to compare VO_2peak during treadmill and cycle ergometry and examine reliability and variability of VO_2peak during these tests in severely overweight youth. For the purpose of the report we used the term VO_2peak instead of VO_2max as recommended by Armstrong and Welsman (1997). They suggested using this term when examining maximal cardiorespiratory responses of young people due to the fact that a plateau in VO_2 maximal exercise stress often does not occur. A plateau in VO_2 as power output increases is typically used as a criteria for reaching VO_2max (McArdle et al., 1996).

Table 2. Peak cardiorespiratory measures during treadmill and bicycle ergometry (n = 21). Data are means (SD). * $p \le 0.05$

Variables	Treadmill	Cycle	t	r
VO_2 (l·min^{-1})	1.57 (.40)	1.46 (.30)	1.0	.77*
VO_2 (ml·kg^{-1}·min^{-1})	21.5 (4.1)	20.3 (5.5)	.8	.72*
VE_{BTPS} (l·min^{-1})	50.3 (13.9)	51.2 (13.0)	-.2	.73*
VCO_2 (l·min^{-1})	1.48 (.42)	1.47 (.33)	.0	.73*
RER	.93 (.05)	1.01 (.08)	-3.6*	.48*
HR (bpm)	185 (10)	183 (11)	.4	.52*

Table 3. Intraclass correlations and intraindividual variability for peak VO_2 during treadmill and cycle ergometry.

	VO_2 ($l\cdot min^{-1}$)		VO_2 ($ml\cdot kg^{-1}\cdot min^{-1}$)	
	Single Test (R)	**Multi Test (R)**	**Single Test (R)**	**Multi Test (R)**
Treadmill (n= 6)	.96	.97	.93	.96
SEM		.009		1.0
Variability		.5%		2.5%
Cycle (n = 7)	.94	.98	.70	.84
SEM		.04		1.7
Variability		5.7%		6.6%

Note: Variability is intra individual as indicated in the methods.

Recently, investigators have observed that children and adolescents often do not meet the plateau or leveling of VO_2 criteria even though maximal values are obtained (Rivera-Brown et al., 1992; Rivera-Brown et al., 1995; Armstrong et al., 1996). Also, large fluctuations are often observed in RER and HR at max (Rowland, 1993). Recently Loftin et al. (2003) found a blunted peak HR response in overweight as compared to normal weight female youth (12-13 years old) during peak treadmill ergometry. The overweight females peak HR averaged 192 ± 9 bpm while the normal weight females averaged 203 ± 8 bpm. In the current study the HR peak during cycle ergometry was similar to the work of Maffeis et al. (1994). However the HR peak during peak treadmill ergometry in the Maffeis study (192 bpm) was slightly higher than values in the current study (185 bpm).

In the present study we observed non-significant differences in peak responses for VO_2, VE_{BTPS}, VCO_2 and HR when treadmill was compared to cycle values. VO_2peak averaged 7.0% and 5.6% higher during treadmill ergometry when expressed in absolute units ($l\cdot min^{-1}$) or relative ($ml\cdot kg^{-1}\cdot min^{-1}$) units (Figure 1). Others have found VO_2peak to vary from 7 to 13 % higher during treadmill ergometry in children and adolescents when compared to cycle values, therefore the current results are at the low end of expected differences. Maffeis et al. (1994) found higher VO_2peak scores of 9.7% and 12.9% during treadmill ergometry in overweight adolescents. The excess body weight of the current severely overweight subjects may have led to less pronounced differences in VO_2peak when treadmill was compared to cycle ergometry. We speculate that the excess body weight may have limited performance more profoundly during treadmill as compared to cycle ergometry since the body mass must be supported during this type of exercise. Typically, the approximate 10% lower cycle when compared to treadmill values have been attributed, in part to more localized muscle fatigue, reduced peripheral blood flow (Boileau et al., 1977) and a smaller exercising muscle mass (Miles et al., 1980). Also, subjectively, we found the current subjects to prefer the cycle ergometer as they perceived cycling easier to perform than treadmill walking.

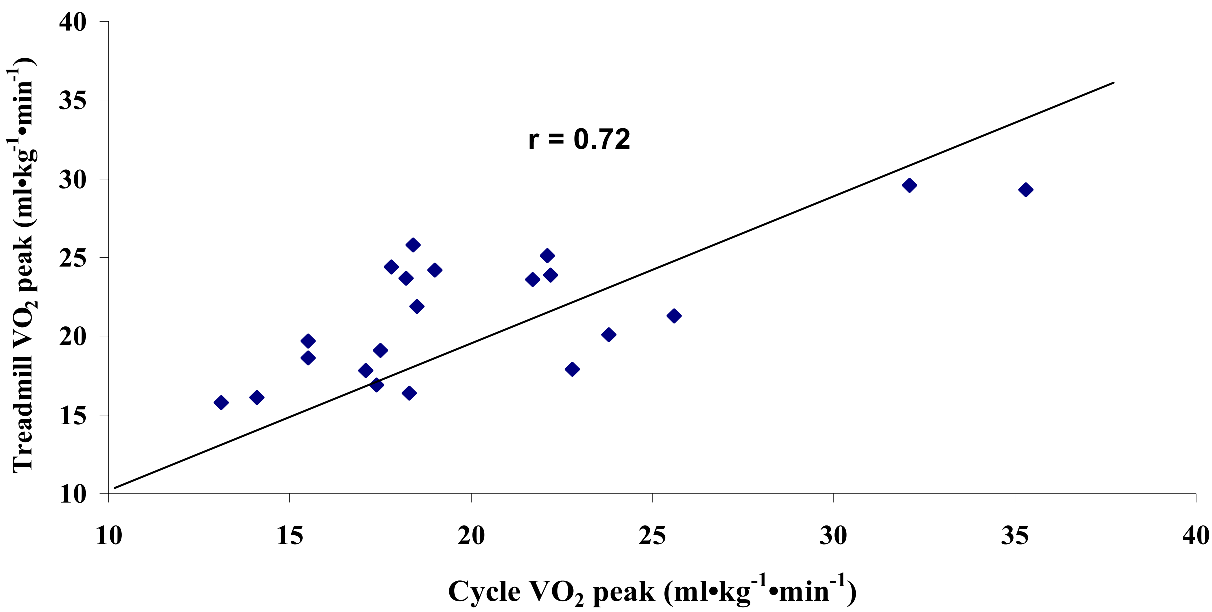

Figure 1. Scatterplot of VO_2peak ($ml\cdot kg^{-1}\cdot min^{-1}$) during treadmill and cycle ergometry.

Significantly higher ($p \leq 0.05$) RER peak values were found during cycle as compared to treadmill ergometry. Boileau et al. (1977) found similar values in youth and attributed the differences to a higher involvement of anaerobic exercise during cycle ergometry. Miles et al. (1980) found similar results during maximal and submaximal (% of max) cycle ergometry in adult women. They also attributed higher RER values to greater anaerobiosis during cycle exercise. On the other hand, Turley et. al. (1995) found higher RER values during maximal treadmill ergometry in youth. Turley et al. (1995) attributed the higher treadmill values to motivation, as the investigators subjectively rated their subjects as exceptionally motivated.

The participants in this study were able to reliably complete the treadmill and cycle ergometry peak tests as indicated by the intraclass correlation coefficients (Table 3). Due to the uniqueness of the subjects (severely overweight) the reliability coefficients were based on small sample sizes. Intraclass correlations ranged from 0.84 to 0.98 for two tests and 0.70 to 0.96 for a single test. Also, no statistical differences ($p < 0.05$) were found when the cardiorespiratory and metabolic parameters were compared from test 1 to test 2. Reliability coefficients for a single test were slightly reduced (Table 3) indicating that peak responses can be obtained with one test (Pivarnik et al., 1996). The lowest correlations were found for VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$) during cycle ergometry however the correlations for VO_2 ($l \cdot min^{-1}$) were quite high (0.94 – 0.98). These results indicate that reliable peak data can be assessed by either ergometer. The strength of the correlation coefficients were similar to other research examining test-retest reliability in normal weight youth during either treadmill or cycle exercise (Boileau et al., 1977; Turley et al., 1995; Pivarnik et al., 1996). Finally, the low standard error values for VO_2 peak were similar to Pivarnik et. al. research (1996) and give further credence to test-retest reliability.

Intra individual variability was lower for the treadmill than the cycle ergometer. In particular, variability ranged from 0.5% to 2.5% for peak VO_2 during treadmill ergometry and 5.7% to 6.6% for the cycle. The treadmill values were lower than the work of Boileau et al. (1977) (4.4%) and Turley et al. (1995) (6.2%), however, the cycle ergometry values were similar.

Peak VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$) of the current participants was lower than previously reported values during either treadmill or cycle ergometry in overweight children and youth (Davies et al., 1975; Huttunen et al., 1986; Zanconato et al., 1989; Rowland, 1991; Maffeis et al., 1994). VO_2peak ranged from 29.1 to 37.9 $ml \cdot kg^{-1} \cdot min^{-1}$ and only 21.2 $ml \cdot kg^{-1} \cdot min^{-1}$ (treadmill) or 20.1 $ml \cdot kg^{-1} \cdot min^{-1}$ (cycle) in the current participants. BMI, an index of obesity, was also higher in the current youth (33.7) than the other studies (24.8 to 30.4) (Davies et al., 1975; Huttunen et al., 1986; Zanconato et al., 1989; Rowland, 1991; Maffeis et al., 1994). In addition to age, gender and training status, adiposity level may influence VO_2peak relative to BW. Along with VO_2peak relative to BW, we suggest including VO_2peak in absolute units ($l \cdot min^{-1}$) or allometric scaled VO_2 (Loftin et al., 2001) when comparing participants of various adipose levels.

CONCLUSION

In conclusion, VO_2peak, VE_{BTPS}, VCO_2, and HR were statistically not different ($p \leq 0.05$) when treadmill was compared to cycle ergometry during peak exercise in severely overweight youth. Moreover, test-retest or single trial reliability correlation coefficients were quite high for VO_2peak during treadmill and cycle ergometry testing. Intra individual variability was in the expected range for treadmill ergometry and higher than expected for cycle ergometry, although SEM's were low for repeated measures VO_2 for both ergometers. These results suggest that both cycle and treadmill ergometry provide valid and reliable methods to examine VO_2peak in overweight youth. Cycle ergometry may be a preferred method for severely overweight youth as it provides a modality that supports the excess weight of the participants.

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KEY POINTS

- Treadmill peak VO_2 higher than cycle ergometry in severely overweight youth.
- VO_2peak test-retest or single trial reliability high in both treadmill and cycle VO_2 peak.
- Standard errors of measure low for both treadmill and cycle VO_2peak.

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