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VO2Max Comparison Between Seated and Standing Ergometry

Andrew Bosak
Western Kentucky University

VO_2MAX COMPARISON BETWEEN SEATED AND STANDING CYCLE ERGOMETRY

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Date Recommended 7-13-01

Matt Green

Director of Thesis

Thad R. Crews

Randall E. Deere

Elmer Gray

Dean, Graduate Studies and Research

8/1/01

Date

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Directed by: Dr. James M. Green, Dr. Thaddeus R. Crews, and Dr. Randall E. Deere

Department of Physical Education and Recreation Western Kentucky University

Maximum oxygen consumption (VO_2max) represents the highest rate at which oxygen can be consumed and utilized to produce energy sustaining aerobic activity. VO_2max is regarded as the gold standard for assessing aerobic fitness and is essential for prescribing appropriate exercise intensities. Therefore, accurate determination of VO_2max is vital. Usually, VO_2max is obtained when an individual reaches volitional exhaustion during a Graded Exercise Test (GXT). Previous studies show VO_2max during standing cycle ergometry protocols and treadmill protocols to be similar, while seated cycle ergometry VO_2max values are lower. Conversely, other studies show seated and standing cycle ergometry VO_2max to be comparable. Because previous studies are equivocal, the purpose of the current study was to compare VO_2max between seated and standing cycle ergometry protocols.

In a counterbalanced order, male (n=14) and female (n=22) average fit volunteers completed a maximal exertion seated cycle ergometry protocol (SIT) and a maximal exertion standing cycle ergometry protocol (STD). Cadence for each protocol was 60 revolutions per minute (rpm), with resistance being increased 30 Watts each minute until volitional exhaustion. SIT required individuals to perform a maximal exertion test and remain seated until volitional exhaustion. For STD, subjects completed the same protocol; however, when the subjects felt they could no longer continue in a seated position, they were required to stand and perform "standing cycling" to volitional exhaustion.

VO_2max (ml/kg/min), heart rate (HR) (b/min), respiratory exchange ratio (RER), and ventilation (V_E) (L/min) were compared between SIT and STD using a Multivariate Analysis of Variance (MANOVA). Results were considered significant at $p \leq 0.05$. VO_2max_{STD} (37.93 ± 8.01) was significantly greater than VO_2max_{SIT} (36.82 ± 6.63), while HR_{STD} (189.7 ± 9.5) was significantly greater than HR_{SIT} (187.3 ± 9.6). VO_2max_{STD} was on average 1.95% greater than VO_2max_{SIT} with a range of -16.93 to +17.43%, while HR_{STD} was on average 1.23% greater than HR_{SIT} with values ranging from –5.59 to +7.43%. VE_{STD} (86.02 ± 31.64) was not significantly greater than VE_{SIT} (82.64 ± 26.77), while RER_{SIT} (1.23 ± 0.065) was significantly greater than RER_{STD} (1.21 ± 0.096).

Results show a standing cycle ergometry protocol permits significantly higher VO_2max and HR values compared to a seated protocol. Twenty out of thirty-six subjects (55.6%) achieved a higher VO_2max and 25/36 (69.4%) recorded a higher peak HR during STD. The current results suggest a standing cycle ergometry protocol should be considered for implementation when cycle ergometry is the selected mode. However, future research should seek to determine characteristics of subjects who do and do not benefit from a standing versus seated protocol.

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Chapter One

Introduction

Maximum oxygen consumption (VO_2max) represents the highest rate at which oxygen can be consumed and utilized to produce energy sustaining aerobic activity. VO_2max is regarded as the gold standard for assessing aerobic fitness and is acknowledged as a substantial backbone for prescribing appropriate exercise intensities. Therefore, accurate determination of VO_2max is vital.

During the period of 1923-1924, Nobel Prize winner A. V. Hill coined the term maximal oxygen uptake. He concluded a) there is an upper limit to VO_2max, b) there are interindividual differences in VO_2max, c) a high VO_2max is a prerequisite for success in middle and long-distance running as well as other aerobic events, and d) VO_2max is limited by the ability of the cardiorespiratory system to transport O_2 to the muscles (Basset and Howley, 2000).

Throughout history, VO_2max has been assessed during numerous exercise modes such as treadmill, rowing, and cycle ergometry. Different modes and protocols have been compared to determine which protocol and/or mode permits the highest VO_2max (Beasley, Fernhall, & Plowman, 1989; Coast, Coast, and Welch, 1986; Faria, Dix, and Frazer, 1978; Lavoie, Mahoney, and Marmelic, 1978; McArdle, Katch, and Katch, 1986; Mckay and Banister, 1976; Moffat and Sparling, 1985; Pivarnik, Mountain, Graves, and Pollock, 1988; Ricci and Leger, 1983; and Welbergen and Clijsen, 1990). Treadmill protocols typically elicit the highest VO_2max values (Tanaka et al, 1987). For cycle ergometry, standing as well as seated protocols have been examined to determine if respective VO_2max values differ (Kelly, Serfass, and Stull, 1980; Montgomery, Titlow, and Johnson, 1971; Nakadomo, Tanaka, Watanabe, and Fukuda, 1987; Ryschon and Stray-Gundersen, 1991; Swain and Wilcox, 1992; Tanaka, Bassett, Best, and Baker, 1996; and Tanaka, Nakadomo, and Moritani, 1987). However, this research has been equivocal and further study is warranted to provide a more definitive answer.

Compared to seated cycle ergometry, treadmill exercise usually permits a higher VO_2max, due to the activation of more muscle mass and less pronounced leg fatigue. One of the more common VO_2max tests implemented in exercise physiology labs is the Bruce treadmill protocol (Beasley et al, 1989; Fernhall and Kohrt, 1990; Kelly et al, 1980; Lavoie et al, 1978; Marsh and Martin, 1993; Moffat and Sparling, 1985; Ryschon and Stray-Gunderson, 1991; Verstappen, Huppertz, and Snoeckx, 1982; and Welbergen and Clijsen, 1990). Despite greater VO_2max values obtained during treadmill exercise, cycle ergometry has many advantages including preference of subjects to use the cycle ergometer during a VO_2max test, adaptability, safety, ease of calibration, and subjects' tolerance of non-weight-bearing exercise (Mckay and Banister, 1976; and Pivarnik et al, 1988). Therefore, scientists have continued to explore ways to manipulate cycle ergometry protocols to allow subjects to attain the highest possible "cycling" VO_2max (Faria et al, 1978; Heil, Derrick, and Whittlesey, 1997; Kelly et al, 1980; Lavoie et al, 1978; McKay and Banister, 1976; Moffat and Sparling, 1985; Nakadomo et al, 1987; Tanaka and Maeda, 1984; and Tanaka et al, 1987).

Previous experiments provide conflicting results regarding VO_2max during seated and standing cycling protocols. Kelly et al (1980), Nakadomo et al (1986), and Tanaka et al (1987) concluded that a standing protocol produced a higherVO_2max compared to a seated protocol. Similarily, Tanaka et al (1996) showed the standing position during four percent incline cycling produced a greater VO_2max compared to the seated position, while Ryschon and Stray-Gundersen (1991) showed incline (4%) standing cycle ergometry to be less economic (10.8% greater submaximal VO_2) than the seated position during sub-maximal cycling. Conversely, Tanaka et al (1996) found no significant differences in VO_2max between standing and seated cycle ergometry at zero percent incline, while Montgomery et al (1978) also determined that standing and seated cycle ergometry VO_2max values were not significantly different.

Statement of the Problem

The purpose of this study was to compare VO_2max between standing and seated cycle ergometry protocols in female and male subjects.

Hypotheses

The study consisted of four statistical (null) hypotheses and their respective alternative hypotheses. All hypotheses are stated below:

$H_{\emptyset 1}$: Seated and Standing cycle ergometry VO_2max will not be significantly different.

$A_{\emptyset 1}$: Standing cycle ergometry VO_2max will be significantly > seated VO_2max.

$H_{\emptyset 2}$: Seated and standing cycle ergometry peak Respiratory Exchange Ratio (RER) will not be significantly different.

$A_{\emptyset 2}$: Standing cycle ergometry peak RER will be significantly > seated peak RER.

$H_{\emptyset 3}$: Seated and standing cycle ergometry peak ventilation (V_E) will not be significantly different.

$A_{\emptyset 3}$: Standing cycle ergometry peak V_E will be significantly > seated peak V_E.

$H_{\emptyset 4}$: Seated and standing cycle ergometry peak heart rate (HR) will not be significantly different.

$A_{\emptyset 4}$: Standing cycle ergometry peak HR will be significantly > seated peak HR.

Significance of the Study

Finding ways to achieve the highest cycling VO_2max has important implications in exercise prescription and fitness evaluation. Therefore, the results of the current study will examine whether standing cycling VO_2max values are significantly greater than seated VO_2max values, which may support the use of a standing cycle ergometer protocol for all cycle ergometry Graded Exercise Tests (GXT). The use of such a protocol may generate the highest cycle ergometry VO_2max values. In terms of gender, prior research has tested only male subjects. Therefore, it was of practical importance to administer the standing and seated cycle ergometry protocol to female subjects in the current study.

Limitations

Limitations of the study, which cannot be controlled, were subject reliability, effort and motivation.

Delimitations

Delimitations of the study, which are choices that the experimenter makes to affect a workable research problem, were gender, age, testing times, and the subjects' fitness levels.

Assumptions

It can be assumed that motivation was equally provided to the subjects during all STD and SIT trials, and that each individual achieved peak metabolic values. Also, assumptions can be made that calibration of equipment prior to each test produced valid and reliable results.

Definition of Terms

- Cycle Ergometry – Stationary cycling
- Force – That which changes or tends to change the state of rest or motion in matter; expressed in Newtons (Foss & Keteyian, 1998)
- Graded Exercise Tests (GXT) – Used to measure maximal oxygen consumption
- Heart Rate (HR) – The number of beats per minute of the heart (b/min)
- Respiratory Exchange Ratio (RER) – The ratio of the amount of carbon dioxide produced by the body to the amount of oxygen consumed [VCO_2/VO_2]
- RPM – Cycle ergometry pedal revolutions per minute
- Saddle – Cycle ergometer seat
- Toe Clips/Stirrups – Straps or clips on the cycle ergometer pedals that secure the foot to the individual pedals
- Ventilation (V_E) – The movement of air in and out of the lungs, measured in liters per minute (L/min)
- VO_2max – The maximal rate at which an individual can consume oxygen during the performance of all out, exhaustive exercise; expressed in liters per minute (L/min) or milliliters per kilogram per minute (ml/kg/min) (Foss & Keteyian, 1998)

Chapter Two

Review of Related Literature

VO_2max may be assessed during numerous exercise modes such as treadmill, rowing, and cycle ergometry. Different modes and protocols have been compared, such as treadmill and cycle ergometry, to determine which protocol and mode elicits the highest VO_2max (Beasley et al, 1989; Kelly et al, 1980; McKay and Banister, 1976; Moffat and Sparling, 1985; Montgomery et al, 1971; Nakadomo et al, 1987; Pivarnik et al, 1988; Ricci and Leger, 1983; Tanaka et al, 1996; Tanaka and Maeda, 1984; Tanaka et al, 1987; and Welbergen and Clijsen, 1990). For cycle ergometry, standing as well as seated protocols have been examined (Kelly et al, 1980; Montgomery et al, 1971; Nakadomo et al, 1987; Ryschon and Stray-Gundersen, 1991; Tanaka et al, 1996; Tanaka and Maeda, 1984; and Tanaka et al, 1987). However, this research has been conflicting, which warrants further study regarding seated and standing cycle ergometry VO_2max test protocols.

In 1978, Montgomery et al concluded, for five male subjects, that VO_2max during standing cycle ergometry (57.35 ml/kg/min) was not significantly different than seated cycle ergometry (49.30 ml/kg/min). Tanaka et al (1996) also found no significant differences between seated (66.4 $\pm$ 1.6 ml/kg/min) and standing (66.4 $\pm$ 1.7 ml/kg/min) VO_2max during level cycle ergometry for seven competitive male cyclists. Conversely, in a sub-study, Tanaka et al (1996) found, for seven male subjects cycling at a four percent incline, a greater VO_2max (2.82%) for standing (56.8 $\pm$ 0.9 ml/kg/min) vs. seated (55.2 $\pm$ 0.9 ml/kg/min) cycle ergometry. Also, Ryschon and Stray-Gundersen (1991) concluded, with ten cyclists (eight males and two females), that standing submax VO_2

values were 10.8% higher than seated values during four percent incline standing cycling. Kelly et al (1980) determined, for twelve male university students, that standing (57.91 $\pm$ 5.74 ml/kg/min) during a cycle ergometry VO_2max test produced a significantly greater (4.4%) VO_2max compared to the seated position (55.12 $\pm$ 6.98 ml/kg/min). Also, Nakadomo et al (1986) concluded that, in 22 male subjects, VO_2max was 17% higher while standing as compared to the seated position. Support of level standing cycling ergometry eliciting higher VO_2max values continued when Tanaka et al (1987) showed that 14 well-trained runners, eight rowers, and six average fit males attained higher VO_2max values when standing as compared to seated cycle ergometry.

In previous research, all standing cycling protocols varied in terms of when to stand during trials, duration of standing, protocol duration, cadence, fitness levels of subjects, and number of subjects. The differences among procedures and methodology may partially explain the contradictory results.

Duration of Standing and Cue to Stand

The main objective of a cycle ergometry GXT is to obtain the highest possible VO_2max. However, McKay and Banister (1976) note that alternate standing and sitting bouts and/or standing prematurely may contribute to earlier fatigue since the additional energy requirement would result in reduced metabolic efficiency, which may prevent their acquisition of a "true" VO_2max.

In Montgomery et al (1971), subjects stood throughout the entire VO_2max test, yet during the standing trial in Tanaka et al (1996), subjects were allowed to alternately stand or sit throughout the duration of the test, but were required to stand for the last few minutes of the test. Kelly et al (1980) showed greater standing VO_2max values compared to seated cycle ergometry while following the same alternate standing protocol as Tanaka et al (1996). As for the remaining studies showing a greater VO_2max during standing cycle ergometry, subjects were required to stand and continue pedaling when they could no longer continue in the seated position (Nakadomo et al, 1987;and Tanaka et al, 1987). However, for incline cycling, Ryschon and Stray-Gundersen (1991) and Tanaka et al (1996) subjects were required to stand during the entire five minute maximal cycle ergometry protocol.

Protocol Duration

The American College of Sports Medicine states that GXT's should last eight to twelve minutes, which provides adequate time for a "true" VO_2max to be achieved (Balady, Berra, Golding, Gordon, Mahler, Myers, and Sheldahl, 2000). However, incline protocols of Tanaka et al (1996) and Ryschon and Stray-Gundersen (1991) lasted only five minutes, whereas Montgomery et al (1971), Kelly et al (1980), Nakadomo et al (1987), and Tanaka et al (1987) utilized level protocols adhering to ACSM guidelines. Thus, adequate protocol duration may have allowed determination of a "true" VO_2max in Kelly et al, 1980; Tanaka et al, 1987, and Nakadomo et al, 1987; and not in Montgomery et al, 1971; and sub-study of Tanaka et al, 1996.

Subject Numbers and Variation

Fitness level, as well as the type of athlete and gender can affect VO_2max values (Foss and Keteyian, 1998). For example, trained cyclists achieve higher VO_2max values during cycle ergometry compared to sedentary individuals and trained runners (Tanaka et al, 1996). This trained versus untrained comparison supports the notion that athletes who train in a certain mode of exercise can attain a higher VO_2max in that specific mode

(Fernhall and Kohrt, 1990; Ricci and Leger, 1983; Tanaka et al, 1996; and Verstappen et al, 1982). Also, males tend to have higher VO_2max values than females due to greater lung capacity and greater amounts of hemoglobin (Foss and Keteyian, 1998). Subjects in previous studies varied in terms of fitness level and preferred mode of exercise, which may have influenced results. Montgomery et al (1971) tested sedentary males; Kelly et al (1980) tested fit male university students; Tanaka et al (1996) tested competitive male cyclists; Tanaka et al (1987) tested averagely fit males, male runners, and male rowers; and Ryschon and Stray-Gundersen (1991) tested trained male and female cyclists.

Most studies have also been plagued by low subject numbers (Montgomery et al, 1971, n = 5; Kelly et al, 1980, n = 12; Tanaka et al, 1987, n = 28; Nakadomo et al, 1987, n = 22; Ryschon and Stray-Gundersen, 1991, n = 10; and Tanaka et al, 1996, n = 7). The low subject numbers may have also contributed to the equivocal results for standing and seated cycle ergometry.

Protocol RPM's

Another important component of cycle ergometry protocols is the revolutions per minute (rpm). As noted earlier, leg fatigue, particularly in the upper thigh, may cause an individual to finish a cycling GXT prematurely (McKay and Banister, 1976). Lower rpm tend to increase leg fatigue (Beasley et al, 1989). Typically, for untrained individuals, 40-60 rpm provide the most economical cadences, yet 80-120 rpm yield the greatest VO_2max and lowest perceived leg fatigue at similar workloads (Beasley et al, 1989; and Marsh and Martin, 1993). Cyclists on the other hand, prefer to cycle at 90 rpm (Marsh and Martin, 1993). However, disparity does exist between the optimal cadences for trained and untrained individuals. Beasley et al (1989) and Pivarnik et al (1988) showed there were no differences in VO_2max and peak HR at 50 rpm and 90 rpm with trained male subjects, while Coast, Cox, and Welch (1986) showed the most economic range of rpm for this group was 60-80. Swain et al (1992) determined that VO_2max and HR were actually lower at higher (84) rpm vs lower (41) rpm. Hagan, Weis, and Raven (1992) concluded that, at higher rpm, (90 rpm vs 60 rpm) HR, V_E, and cardiac output will be greater, while cycling economy decreases. In contrast to the results of Hagan et al (1992), Nickleberry and Berry (1996) determined that recreational cyclists were able to increase their time to exhaustion by six minutes, while competitive cyclists continued eight minutes longer at 80 versus 50 rpm.

The disparity among optimal pedal frequencies plays an important part in analyzing the previous standing protocols. Montgomery et al (1971) used 60-70 rpm, Kelly et al (1980) used 60 rpm, Ryschon and Stray-Gundersen (1991) used 60 & 80 rpm, Tanaka et al (1996) used 60 rpm, and Tanaka et al (1987) used 60 rpm. Despite the rpm being similar for each study, fitness levels were not considered, which may have resulted in optimal rpm and fitness levels being mismatched, possibly confounding the results.

In examining standing cycle ergometry, it may be prudent to recruit a more homogeneous group with respect to fitness and with representatives of both genders being tested. This process may improve validity in comparisons of standing and seated VO_2max values, which can be applied to a larger population. Based on previous results, it is unclear whether standing VO_2max values will be greater than seated VO_2max values.

Chapter Three

Methodology

The purpose of this study was to examine the possible differences in VO_2max between seated and standing cycle ergometry.

Description of Subjects

Subjects were 14 male and 22 female apparently healthy volunteers from 18-28 years of age. Subjects were of average fitness. All subjects were made aware of the risks and requirements of participating in the study and signed a written informed consent prior to any testing. To ensure the safety of the subjects, all individuals were required to complete a physical activity readiness questionnaire (PAR-Q) and a health status questionnaire prior to data collection.

Instruments Utilized

Subjects were tested on a model 824E Monark Cycle Ergometer. Each subject wore a Hans Rudolph facemask with expired gas being collected and VO_2 being analyzed by a Sensormedics 2900 Metabolic Measurement System. Individuals also wore a Polar Heart Rate Monitor (Model Polar Beat HRM) to determine exercise heart rate. Body fat percentage was determined using Lange skinfold calipers with a 3-site skinfold method. Weight and height were measured using a detecto balance type scale with an attached measuring rod.

Procedures

Descriptive data was collected immediately prior to the initial VO_2max test. After subjects reported to the lab, an explanation of the study was provided and the initial screening procedures were administered. Instructions regarding the exercise trial were also provided to the subjects. Subjects were then assessed for height, body weight, and body fat percentage using a 3-site skinfold technique (Pollock, Schmidt, and Jackson, 1980).

Design and Analysis

Subjects underwent two VO_2max tests (SIT and STD) on a cycle ergometer. Because subjects were of average fitness, cadence was set at 60 rpm for the duration of the tests (Beasley et al, 1989; and Marsh and Martin, 1993). Initially, subjects warmed up at a resistance of 30 watts for four minutes at 60 rpm. Every minute thereafter resistance was increased 30 watts until the subject reached volitional exhaustion. SIT required the individual to stay seated until the test was terminated (at volitional exhaustion), while STD required the individual to stand at the point at which they felt they could no longer continue in a seated position, and continue to perform "standing cycling" to volitional exhaustion. All tests were stopped when subjects reached volitional exhaustion or when testers felt it was not safe for the subjects to continue. At the completion of each VO_2max test, subjects were monitored during a low intensity cool-down. SIT and STD lasted approximately seven to fifteen minutes and were completed in a counterbalanced order on two separate days with three to seven days between each session.

Expiratory gas was analyzed using a Sensormedics 2900 Metabolic cart, which was calibrated prior to each test using a three-liter syringe and gases of known concentration. The system provided updates of metabolic data (VO_2, V_E, RER) every 20 seconds. Also, a Polar Heart Rate monitor was used to monitor heart rate response (HR) every 60 seconds. Heart rate, VO_2max, RER, and V_E were compared between SIT and STD. The highest observed values for metabolic data were considered "max" values for each respective cycle ergometry trial. The criteria for achieving a "true" VO_2max were a) failure of HR to increase with further increases in exercise intensity, b) RER exceeded +1.15, and c) a rating of perceived exertion (RPE) of more than 17 (Balady et al, 2000). In the present study, meeting two out of the three criteria satisfied the requirement for achieving a "true" VO_2max. VO_2max, HR, RER, and V_E were analyzed using a multivariate repeated measures analysis of variance (MANOVA). Mean time to exhaustion for STD and SIT were compared using a paired t-test. Results were considered significant at $p \leq 0.05$.

Chapter Four

Results

Descriptive characteristics of all subjects are displayed in Table 1. Physiological responses to seated and standing cycle ergometry are presented in Table 2. The MANOVA revealed that VO_2max_{STD} was significantly greater than VO_2max_{SIT} with a mean difference of 1.11 ml/kg/min. Also, HR_{STD} was significantly greater than HR_{SIT} with a mean difference of 2.39 b/min. For V_E, V_{ESTD} was not significantly different ($p = 0.08$) than V_{ESIT}. However, RER_{SIT} was significantly greater than RER_{STD}.

Regarding mean time to exhaustion, subjects cycled 10:15 $\pm$ 2:21 minutes during SIT, with individuals cycling between 7-15 minutes. Although the difference only approached significance ($p = 0.064$), subjects were able to cycle on average eleven seconds longer (10:26 $\pm$ 2:06 minutes) during STD, with participants cycling between seven minutes, twenty seconds and fifteen minutes, twenty seconds. When subjects were in the standing position, the mean duration of standing cycle ergometry time to volitional exhaustion was 50.42 $\pm$ 15.57 seconds.

Chapter Five

Discussion/Conclusion

Previous results regarding standing cycle ergometry have been equivocal. Kelly et al (1980), Nakadomo et al (1987), and Tanaka et al (1987) showed significantly greater standing VO_2max, while Montgomery et al (1971), and Tanaka et al (1996) showed no significant differences in seated and standing VO_2max. Similar to the results of Kelly et al (1980), Tanaka et al (1987), and Nakadomo et al (1987), as well as Tanaka et al (1996), the current results suggest that VO_2max_{STD} and HR_{STD} are significantly greater than VO_2max_{SIT} and HR_{SIT} (Table 2).

VO_2max & HR

The current study showed a significantly greater (1.95%) VO_2max and a significantly greater (1.23%) HR during STD compared to SIT. The greater VO_2max and HR during STD can be explained by a variety of reasons. Based on previous research, it is likely with greater force production, a larger amount of muscle mass was involved during STD (Nordeen-Strider, 1977). Also, standing during STD may have activated more muscle mass, as the legs supported the individual's body weight as opposed to being supported by the saddle during SIT (Nakadomo et al, 1987; Ryschon and Stray-Gundersen, 1991; and Tanaka et al, 1987). Also, as noted by Ryschon and Stray-Gundersen (1991), and Tanaka et al (1987), during standing cycle ergometry, the upper body is involved to a greater degree in torso stabilization and purposeful side-side rocking, compared to seated cycling. Kelly et al (1980) and Ryschon and Stray-Gundersen (1991) suggested the standing cycle ergometry protocol provides more extensive involvement of the arm and leg muscles thereby eliciting greater blood flow and higher work output contributing to a higher peak HR and VO_2max, which may have also contributed to the findings of the current study.

Tanaka et al (1987) suggested that decreases in subject cycling economy and attenuated leg fatigue might also explain the greater VO_2max_{STD} and HR_{STD}. Ryschon and Stray-Gundersen (1991) note that greater cardiorespiratory and metabolic requirements of the standing position decreases the efficiency of the rider, yet provides an increase in the total work output. For leg fatigue, subjects in the current study often verbally reported feelings of intense local discomfort and fatigue in the region of the quadriceps muscle while in the seated position, when near or at volitional exhaustion. This leg fatigue and discomfort coupled with gradual increases in resistance may have limited the ability of the subject to continue cycling in the seated position (Nakadomo et al, 1987; Tanaka and Maeda, 1984; and Tanaka et al, 1987). However, many subjects verbally reported that at the onset of standing cycling, leg fatigue and local discomfort was comparatively less than during seated cycling, which could have accounted for the extended time to fatigue during STD (Ryschon and Stray-Gundersen, 1991; and Tanaka et al, 1987). Variations in perceived feelings might have been due to the redistribution of the workload over a greater muscle mass and alterations in the muscle recruitment pattern (Ryschon and Stray-Gundersen, 1991).

Another factor that may have contributed to greater VO_2max during STD is the increases in joint angles when the individual comes out of the saddle and performs standing cycling. Previous research suggests when standing, the hip, knee, and ankle joint excursions increase, which provides a greater range of motion within the respective joints (Nordeen-Snyder, 1977). Although not measured in the current study, it is possible that increases in the hip, knee, and ankle joint angles allowed for a more advantageous muscular force production and subsequent extended time to fatigue (Shennum and deVries, 1976; Nordeen-Snyder, 1977; and Heil, Derrick, and Whittlesey, 1997).

Tanaka et al (1996) and Ryschon and Stray-Gundersen (1991) showed greater standing cycle ergometry HR. Although those differences occurred during a four percent incline protocol, significantly greater HR (1.23%) occurred during the current study which utilized a level protocol. The extended time to fatigue allowed by standing, may have attributed to a higher HR because earlier termination of the test due to leg fatigue and discomfort may have interfered with attainment of a true max HR.

V_E & RER

Although only approaching significance ($p = 0.08$), a 0.83% greater V_E occurred during STD compared to SIT. The increases in V_E can be attributed to some of the reasons that likely contributed to a greater VO_2max during standing cycle ergometry. Generally when V_E increases, so too does VO_2 (Foss and Keteyian, 1998).

As previously mentioned, when an individual leaves the seated cycle ergomerty position to stand, a greater involvement of upper and lower body muscle mass occurs. The activation of more muscle mass may allow for greater work output, which increases oxygen requirements of the muscles, and in turn ventilation increases. Cardiac output is also increased when participating in the standing position, which contributes to higher VO_2max and V_E (Kelly et al, 1980). Also, because lower leg fatigue may be altered in the standing position, V_E increases, as the subjects are able to extend time to exhaustion.

For RER, SIT showed a significantly greater (2.31%) RER as compared to STD. Although SIT produced significantly greater RER compared to STD, the difference was of little practical significance. All RER values in both STD and SIT surpassed the criteria indicative of a "true" VO_2max (+1.15).

The current study showed VO_2max_{STD} and HR_{STD} were significantly greater compared to SIT. However, despite the significant differences, it is important to note that discrepancies between the present study and previous studies (Montgomery et al, 1971 & Tanaka et al, 1996) could be a result of the protocol differences, variations in fitness levels, and low subject numbers. Many subjects benefited from the STD protocol as 20 of 36 (55.6%) individuals had greater VO_2max (up to 13.64%) and 25 of 36 (69.4%) subjects had greater peak HR (up to 7.43%). While means were significantly different, it should be noted that interindividual variability was high and some subjects had a much lower VO_2max during STD. Differentiating between those who respond positively and negatively to a standing protocol is difficult and was beyond the scope of the current study.

Conclusions

The results of the current study support previous findings showing a greater VO_2max during standing versus seated cycle ergometry (Kelly et al, 1980; Nakadomo et al, 1987; and Tanaka et al, 1987). Results of the current study also show significantly greater HR_{STD}. The current results support the use of a test protocol that allows an individual to stand during a cycle ergometry GXT. Therefore, since a higher VO_2max value was elicited using the standing protocol in the current study, a standing protocol should be considered for implementation when individuals are assessed for cardiorespiratory responses to maximal work using cycle ergometry. Future research should seek to determine characteristics of subjects who do and do not benefit from a standing versus seated protocol.

Appendix A

Table 1: Descriptive Characteristics of Subjects (n=36)

	Males (n=14)	Females (n=22)	All Subjects
Age (years)	23.07 $\pm$ 2.97	19.73 $\pm$ 1.20	21.03 $\pm$ 2.63
Height (inches)	70.93 $\pm$ 3.17	65.59 $\pm$ 2.11	67.67 $\pm$ 3.66
Weight (lbs)	190.14 $\pm$ 23.36	139.00 $\pm$ 15.79	158.89 $\pm$ 31.49
Body Fat (%)	10.90 $\pm$ 4.45	21.41 $\pm$ 4.20	17.33 $\pm$ 6.71

-Values are means and standard deviations

APPENDIX B

Table 2: Physiological Responses During SIT and STD

	VO_2max (ml/kg/min)	HR (b/min)	V_E (L/min)	RER
SIT	36.82 ± 6.63	187.3 ± 9.6	82.64 ± 26.77	1.23 ± 0.065
STD	37.93 ± 8.01*	189.7 ± 9.5*	86.02 ± 31.64	1.21 ± 0.096*

-Values are means and standard deviations
* Significantly different ($p \leq 0.05$) (STD versus SIT)

APPENDIX C

Bike Max VO_2

Subject:________________ Date:_______ Pre. HRmax:______ SIT OR STAND

Chest/Tricep:________ Ab/Iliac:_______ Thigh:_______ Body Fat%_______

Age:____________ Gender:____________ Ht:_____________ Wt:____________

Minute	Workload	Heart Rate	VO_2	RPE (O/L/C)	VE
0 – 1	0.5	_______	_______	___/___/___	_______
1 – 2	0.5	_______	_______	___/___/___	_______
2 – 3	0.5	_______	_______	___/___/___	_______
3 – 4	0.5	_______	_______	___/___/___	_______
4 – 5	1.0	_______	_______	___/___/___	_______
5 – 6	1.5	_______	_______	___/___/___	_______
6 – 7	2.0	_______	_______	___/___/___	_______
7 – 8	2.5	_______	_______	___/___/___	_______
8 – 9	3.0	_______	_______	___/___/___	_______
9 – 10	3.5	_______	_______	___/___/___	_______
10 – 11	4.0	_______	_______	___/___/___	_______
11 – 12	4.5	_______	_______	___/___/___	_______
12 – 13	5.0	_______	_______	___/___/___	_______
13 – 14	5.5	_______	_______	___/___/___	_______
14 – 15	6.0	_______	_______	___/___/___	_______
15 – 16	6.5	_______	_______	___/___/___	_______
16 – 17	7.0	_______	_______	___/___/___	_______

VO_2 max:_______ Max HR:_______ VT (%):_________ VT ($V0_2$):_________

RPE (VT):_______ RCT%:__________ RCT(VO_2):__________

APPENDIX D

Informed Consent Statement

Comparison of Maximum Exercise Capacity Between Standing And Seated Stationary Cycling

The purpose of this research project is to compare maximum exercise capacity between seated stationary cycling and standing stationary cycling

Requirements

As a volunteer in this research project you will be required to do the following:

1) Perform 2 separate maximal exertion exercise trials; a) Seated stationary cycling and b) Standing stationary cycling.

YOU SHOULD NOT PARTICIPATE IF YOU:

1-- ARE PREGNANT OR MIGHT BE PREGNANT
2-- YOU ARE TAKING DRUGS (PRESCRIPTION OR ANY OTHER)
3-- HAVE A FAMILY HISTORY OF HEART, VASCULAR, OR KIDNEY DISEASE.

The exercise trials will be completed on 2 separate days and will be as follows:

A) Maximal exertion seated cycling test. During this trial you will exercise on a stationary bike for approximately 12-18 minutes depending on your current fitness level. You will pedal the bike at 60 revolutions per minute at a light intensity for 4 minutes. Every minute thereafter, the resistance will be slightly increased to make the exercise more difficult. When you feel you can no longer continue at the required pace, the test will be stopped and you will be monitored during a low intensity cool-down. The test may also be stopped when testers feel it is not safe for you to continue.

B) Maximal exertion standing cycling test. During this trial you will exercise on a stationary bike for approximately 12-18 minutes depending on your current fitness level. You will pedal the bike at 60 revolutions per minute at a light intensity for 4 minutes. Every minute thereafter, the resistance will be slightly increased to make the exercise more difficult. When you feel you can no longer continue at the required pace while seated, you will be allowed to stand and continue pedaling until you feel you no longer can continue. The test will then be stopped and you will be monitored during a low intensity cool-down. The test may also be stopped when testers feel it is not safe for you to continue.

During the cycling tests you will be required to wear a breathing mask. It will cover your nose and mouth but will permit you to freely breath room air. You will also be required to wear a heart rate monitor around your chest near the area of your sternum (breastbone). The monitor resembles a small belt. Each minute you will also be asked to rate, on a scale of 6-20, how difficult the exercise feels.

2) You will be measured for descriptive data including age, height, weight, and gender. Also, percent body fat will be measured using skinfold calipers and lightly pitching you at three locations on your body (Males at the chest, abdomen, and thigh, and Females at the back of the upper arm, side of hip, and the thigh).

3) Prior to participation you MUST complete a physical activity readiness questionnaire (PAR-Q), a health status questionnaire, and the informed consent. These forms will be used to evaluate the safety of your participation as well as your willingness to participate. Any questions you may have about your participation or the forms you complete are welcomed and will be answered to your satisfaction.

Risks Due to Participation

During the tests you will experience severe fatigue particularly near the completion of the tests. Also, you should expect to experience increased respiratory rate (heavy breathing), increased heart rate, and possible lightheadedness. Dizziness, nausea and other uncomfortable symptoms associated with very intense physical exertion could be experienced as well. Although highly unlikely, cardiovascular injury (heart attack or stroke) could also result from intense physical exertion. ACSM (2000) makes the following general statements regarding exercise testing:

1) the risk of death during or immediately after an exercise test is < 0.01%,
2) the risk of myocardial infarction immediately after an exercise test is < 0.04%,
3) the risk of a complication requiring hospitalization (including myocardial infarction) is approximately 0.1%. These statements are made for the general population.

Safety of Participation

Every precaution will be taken to ensure you safety. It is very important that you fully disclose anything that would increase your risk for exercise.

- ***DO NOT*** CONSUME HEAVY FOODS FOR APPROXIMATELY 3 HOURS PRIOR TO EACH LAB SESSION.
- ***DO NOT*** TAKE MEDICATION OF ANY KIND FOR 24 HOURS BEFORE PARTICIPATING IN THE EXERCISE TRIALS.
- ***DO NOT*** CONSUME ANY CAFFEINE ON THE DAYS WHEN YOU ARE PARTICIPATING.
- ***DO*** DRINK PLENTY OF FLUIDS AND AVOID ALCOHOL FOR 24 HOURS BEFORE PARTICIPATING IN THE EXERCISE TRIALS.
- ***DO*** REPORT TO THE LAB EACH TIME WELL-RESTED (NO EXERCISE FOR 24 HOURS PRIOR TO THE LAB SESSION).

IF YOU FEEL ILL AT ANY TIME DURING, BEFORE OR AFTER THIS STUDY LET THE INVESTIGATORS KNOW IMMEDIATELY!!

IF YOU MIGHT BE PREGNANT OR IF YOU ARE TRYING TO CONCEIVE CHILDREN, YOU SHOULD NOT PARTICIPATE IN THE STUDY!!

Benefits of Participation

By participating in this research, you will receive information regarding your aerobic fitness (VO_2 max), ventilatory threshold, height, weight and percent body fat.

Right to Withdraw

It is your right to withdraw from the study at any point. Withdrawing from the study will not adversely affect you in any manner. You should also understand that the investigator might ask you to withdraw from the study.

Privacy

Any information collected about you will be completely confidential. Your participation in the study will not be recognized nor will any personal information about you be made public. Only the primary investigators will have access to any personal information throughout the study. After testing, your information will be coded by numbers and will no longer be paired with your name so your personal information cannot be made public.

Voluntary Consent

If you fully understand what will be asked of you (should you decide to participate), please read and sign the following statement:

I freely and voluntary and without undue inducement or any element of force, fraud, or deceit, or any form of coercion, consent to be a subject in this research project. I understand that my participation is strictly voluntary and that I am free to withdraw my consent and discontinue participation at any time without penalty or prejudice. I also understand that my confidentiality will be protected and that my name will not be associated with the study results. I have been given the right to ask and have answered any questions that I may have regarding this research. I also understand that any other questions that I may have regarding this research or any procedure may be addressed to Andy Bosak (781-7429) or to Dr. Matt Green at the Department of Physical Education and Recreation (745-6035). I have read and understand the above.

Signature: ____________________ Date: ____________________

Address: ____________________ Telephone #: ______________

____

Witness ____________________ Date: ____________________

APPENDIX E

Health Status Questionnaire

Instructions
Complete each question accurately. All information is confidential.

Part 1. Information about the individual

1. name ______________________________ ______________ date
2. mailing address ______________________ ______________ home phone
______________________________ ______________ work phone
3. ______________________________ ______________
person to contact in case of emergency emergency phone
4. age __________
5. circle gender: male female

Part 2. Medical History

6. Circle any who had heart attack before age 50:

Father Mother Brother Sister Grandparent

7. Date of a) last physical exam: _________ (year)

b) last fitness test: __________ (year)

8. List ALL operations you have had and supply the approximate dates of each.

____
____
____

9. Please circle any of the following for which you have been diagnosed or treated by a physician or health professional:

Alcoholism	Anemia, sickle cell	Anemia	Asthma	Back strain
Bleeding trait	Bronchitis, chronic	Cancer	Cirrhosis	Concussion
Congenital defect	Diabetes	Emphysema	Epilepsy	Eye problem
Hypoglycemia	Hyperglycemia	Hyperlipidemia		Hypertension

Heart problem	Kidney problem	Infectious mononucleosis	
Mental Illness	Neck strain	Obesity	Phlebitis
Rheumatoid arthritis	Stroke	Ulcer	Thyroid problem

Other ____

10. List any and all drugs you are currently taking or have taken in the last 6 months:

____

____

____

11. Any of these health symptoms that occurs frequently is the basis for medical attention. Circle the number indicating how often you have each of the following:

5 = very often 4 = fairly often 3 = sometimes 2 = infrequently 1 = practically never

a. cough up blood	1 2 3 4 5	b. abdominal pain	1 2 3 4 5
c. low back pain	1 2 3 4 5	d. leg pain	1 2 3 4 5
e. arm or shoulder pain	1 2 3 4 5	f. chest pain	1 2 3 4 5
g. swollen joints	1 2 3 4 5	h. feel faint	1 2 3 4 5
i. dizziness	1 2 3 4 5	j. breathlessness upon exertion	1 2 3 4 5

Part 3. Health-related behavior

12. Do you now smoke? yes no

13. If yes, indicate number per day:

cigarettes	40 or more	20-39	10-19	1-9
cigars or pipe only	5 or more or any inhaled		less than 5, none inhaled	

14. Do you exercise regularly? yes no

15. How many days per week do you normally spend at least 20 minutes in moderate to strenuous exercise?

0 1 2 3 4 5 6 7 days per week

16. Can you walk 4 miles briskly without fatigue? yes no

17. Can you jog 3 miles continuously at a moderate pace without discomfort? yes no

18. Are you currently trying to conceive children? yes no

****List below everything not already on this questionnaire that might cause you problems in a fitness test or fitness program or any kind of exercise participation.**

____
____
____
____
____

APPENDIX F

*Physical Activity Readiness Questionnaire

Name ______________________________ Date _____________

Please read the questions carefully and answer each one honestly.

yes no 1. Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?

yes no 2. Do you feel pain in your chest when you do physical activity?

yes no 3. In the past month, have you had chest pain when you were not doing physical activity?

yes no 4. Do you lose your balance because of dizziness or do you ever lose consciousness?

yes no 5. Do you have a bone or joint problem that could be made worse by a change in your physical activity?

yes no 6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?

yes no 7. Do you know of any other reason why you should not do physical activity?

*ACSM Guidelines (1995)

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