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Oxygen cost of glideboarding at selected cadences and distance

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OXYGEN COST OF GLIDEBOARDING AT SELECTED
CADENCES AND DISTANCE

A Thesis

Presented to the
School of Health, Physical Education, and Recreation
and the

Faculty of the Graduate College
University of Nebraska

In Partial Fulfillment
of the Requirements for the Degree
Masters of Science

by

Randy Tolle

May 1993

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THESIS ACCEPTANCE

Acceptance for the faculty of the Graduate College,
University of Nebraska, in partial fulfillment of the
requirements for the degree Masters of Science, University
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Abstract

The purpose of this study was to measure the oxygen cost, energy expenditure, and heart rate of glideboarding at selected cadences and distance. The subjects were healthy males (N=30), 19 to 32 years old. They glideboarded at the cadences of 42, 48, and 54 bpm and distance of 1.73 m until steady rate was achieved. (Ten of the subjects repeated the protocol for test-retest reliability.) The oxygen cost was 23.6, 26.7, and 31.8 ml/kg/min for the respective cadences of 42, 48, and 54 bpm. A one-way ANOVA for repeated measures and Tukey's post-hoc tests indicated significant ($p < 0.05$) differences among the cadences. Pearson correlation coefficients and correlated t tests were determined for test-retest data. There were strong correlations of $r=0.83$, 0.94 , and 0.93 for the respective cadences and all t values were not significant ($p > 0.05$). The results indicated that the oxygen cost of glideboarding was comparable to other forms of aerobic exercise. Therefore, it can be assumed that glideboarding may be incorporated into a weight loss or training program. Due to the lack of published data, it is suggested that the oxygen cost of glideboarding be further investigated.

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CHAPTER I

Introduction

Recently, there has been a dramatic increase in the popularity of activities which involve the same lateral movement associated with the glideboard, such as cross-country skiing, and especially skating activities. Other activities which incorporate the lateral movement include basketball, soccer, football, and racquet sports. As a result the glideboard has become a training device for those individuals wishing to improve their performance in activities.

The glideboard, or lateral movement trainer, has been used in the rehabilitation process for injuries since the 1950's (Reese & Lavery, 1991). A glideboard is constructed of Plexiglass, polyethylene, or formica which can vary in length and width. At each end of the glideboard is a stop block. They can both be permanent, or one can be adjusted to the desired length. The subject begins in a slightly crouched position, pushes off of the stop block, glides across the board to the opposite stop block, then repeats the action.

The purpose of the glideboard is to train individuals specifically for lateral movement. Therefore, it effectively trains the adductors, abductors, quadriceps, lateral hip, gluteal muscles, and other minor leg muscles

which are involved in the movement.

Currently no information can be found in the research literature that has explored the oxygen cost (VO₂), energy expenditure (kcal), and heart rate (HR) during exercise on the glideboard. Numerous studies have collected data on these variables of exercise for cycling (Lang, Latin, Berg & Mellion, 1992), walking (Montoye, Ayen, Nagle & Howley, 1985), running (Mayhew, 1977), and skiing (Bilodeau & Boulay, 1991). Therefore, glideboard exercise will be investigated in this study.

Statement of Problem

Current research literature does not contain data on submaximal VO₂, energy expenditure, and submaximal heart rate response while performing the glideboard exercise. Therefore, the purpose of this study was to investigate these variables during glideboard exercise and to compare the oxygen cost of glideboarding to other forms of aerobic exercise.

Statement of Hypothesis

The hypothesis for this study was that as the gliding cadences increase so does the submaximal VO₂, energy expenditure, and heart rate response. Therefore, it was hypothesized that significant differences would be found among these variables at selected cadences. This hypothesis was tested at $p=0.05$.

Delimitations/Limitations

Male subjects (n=30) had to meet the following requirements: (1) 18 to 35 years of age, (2) no contraindicated risk factors (smoking, personal history of heart or lung problems, orthopedic or musculoskeletal joint problems which could be complicated further through participation), (3) no previous experience with glideboard exercise, (4) involved in cardiovascular activity for the prior three months. Cardiovascular activity was defined as exercise that was aerobic in nature, and was performed three times a week for at least 20 min each session.

The subjects were required to participate in three practice sessions prior to the gathering of data to become familiar with the movement. Because there was a great variety of cadences and distances that can be performed on the glideboard, thereby allowing a large range of intensities that exercise may be performed, the cadences were delimited to 42, 48, and 54 beats per minute, and the distance to 1.73 m.

Certain factors may have affected the subjects' performances. The head gear worn to support the tubing that was connected to the metabolic cart may have increased the anxiety level of the subjects and, therefore, increased submaximal $\dot{V}O_2$ values. To help reduce test anxiety, the subjects were required to practice gliding using the head

gear and tubing prior to actual data collection as they familiarized themselves to the gliding movement. Also, the added weight and mass of the head gear and tubing may have decreased the efficiency of the subject, resulting in increased submaximal $\dot{V}O_2$ values.

Another limitation may have been the friction between the socked feet and the glideboard surface. As the sock and sliding surface became worn, the friction level may have increased, resulting in an increased submaximal $\dot{V}O_2$.

Definition of Terms

The following list of terms is provided for clarity:

Conceptual Terms

Submaximal Oxygen Cost (submax $\dot{V}O_2$) - the volume of oxygen consumed during rest and moderate exercise. (Wilmore & Costill, 1988)

Energy Expenditure (EE) - amount of energy in kcal expended to perform activity. (Wilmore & Costill, 1988)

Functional Terms

Full-glide - the action of gliding from one stop block to the opposite then returning to the initial stop block.

Glideboard - training tool consisting of polyethylene surface with two stop blocks, one is permanent, the other is adjustable to the desired length.

Glideboarding (lateral movement) - action involving lateral movement. Subject is in slightly crouched position with lateral side of foot against stop block. He pushes off the stop block, glides across the board to the opposite stop block, then repeats the action.

Steady rate - condition in which the amount of oxygen taken in, transported, and consumed by the body does not fluctuate more than 50 ml/min for two consecutive minutes after a period of at least 5 min of continuous exercise.

Justification

Because no data could be found concerning submaximal $\dot{V}O_2$, energy expenditure, and heart rate responses to glideboard exercise, it therefore seemed logical to investigate these variables at selected cadences on the glideboard. By knowing the energy expenditure of glideboarding at these selected cadences and set distance, intensity can be determined with greater accuracy. This could be used to develop exercise prescriptions for effective weight loss. Also, due to the specificity of the movement, the glideboard could be an excellent training modality for individuals who may wish to maintain or increase cardiovascular endurance and are involved in skating activities and other activities incorporating lateral movements.

CHAPTER II

Review of Literature

The glide board has been in existence since the 1950's, but mainly as a rehabilitative tool and as a training device to improve power in a skater's push-off. Little research has been conducted regarding physiologic responses to endurance training on the glide board. If the glide board is to be used as an aerobic exercise modality, the responses should be comparable to other forms of aerobic exercise. Therefore, the literature examined will provide information about physiology from cycling, running, walking, and skiing studies.

Oxygen Cost of Cycling

Lang, Latin, Berg and Mellion (1992) investigated the accuracy of the American College of Sports Medicine's equation for predicting the $\dot{V}O_2$ of cycle ergometer exercise. The subjects were 60 healthy males, ages 19 to 39 yr old. All were untrained cyclists. A five stage (30, 60, 90, 120, and 150 W) submaximal cycle ergometer test was performed while the subject's $\dot{V}O_2$ was measured. Submaximal $\dot{V}O_2$ at respective workloads were 0.94, 1.23, 1.55, 1.93, and 2.35 L/min. A revised equation was developed based upon the actual $\dot{V}O_2$ -power relationship. The slope was lower and the intercept higher when compared to the ACSM equation. The equation indicated that 1.9 ml/kgm/min is consumed during

steady rate cycle ergometry.

Wilmore, Constable, Stanforth, Buono, Tsao, Roby, Lowdon and Ratliff (1982) conducted a mechanical calibration of four cycle ergometers used in research laboratories. Ten male subjects (mean age 31.1 ± 7.3 yr) volunteered to participate in the study. Each subject rode each bike twice in a randomized order at a rate of 60 rpm and at power outputs of 49, 98, and 147 W. Submaximal $\dot{V}O_2$ was measured using the Beckman Metabolic Measurement Cart. Each test lasted 15 min, and all testing was completed in a two-week period. Results indicated that, at the respective workloads, the submaximal $\dot{V}O_2$ was 0.98, 1.45, and 2.01 L/min. From the results, Wilmore et al. concluded that friction-braked ergometers using a disc-brake were not as reliable as those that provide electrically braked resistance, use a hydraulic system with a Prony brake, and those that use a fabric belt around the rim of the flywheel for resistance.

Fairshter, Walters, Salness, Fox, Mink, and Wilson (1983) evaluated a short-duration maximum exercise test by comparing a 15-sec incremental exercise protocol with a one-min incremental protocol. The subjects were 20 healthy men and women. Fifteen of the 20 subjects were studied using a cycle ergometer and 10 of the 20 subjects were studied on a treadmill. The subjects maximal $\dot{V}O_2$ was calculated from

expired minute volume and expired gas measurements. During cycle ergometry, power output was increased at a rate of 16.3 W increments every 15 sec or every minute up to a possible maximum of 327 W. For the treadmill protocol, speed was first increased in 0.5 mph increments between speeds of 1.0 to 4.5 mph; treadmill grade was then increased in one deg increments up to a maximum grade of 9 deg. If the subjects were not maximally exercised at 4.5 mph, 9 deg grade, then treadmill speed was again increased in 0.5 mph increments to a maximum of 5.5 mph, 9 deg grade. Cycle ergometer results showed $\dot{V}O_2$ max values of 3.42 ± 0.72 and 3.55 ± 0.80 L/min for the 15-sec and one min protocols, respectively. Treadmill exercise results indicated $\dot{V}O_2$ max values of 3.47 ± 1.21 and 3.43 ± 1.16 L/min for the 15-sec and one min protocols, respectively. Fairshter et al. concluded that the data from a 15-sec incremental study was comparable in normal men and women to data from the more commonly used one min incremental protocol. Therefore, he suggested that short-duration incremental tests were appropriate for testing athletically-active subjects.

Energy Cost of Running and Walking

Erickson, Simonson, Taylor, Alexander, and Keys (1945) conducted research on the energy cost of horizontal and grade walking on a motor-driven treadmill. Fifty-four healthy male subjects walked at 16 different combinations of

speeds and grades covering the range from 2.5 to 4.0 mph at 0 to 10 percent grade. Energy expenditure ranges (kcal/min) at the grades of 0.0, 5.0, 7.5, and 10 percent at 2.5 mph were 1.75 to 5.82; at 3.0 mph, 2.65 to 7.38; at 3.5 mph, 3.32 to 9.16; at 4.0 mph, 3.79 to 11.53. The mean $\dot{V}O_2$ of 47 subjects at the 3.5 mph/10 percent grade was 25.97 ml/kg/min. Erickson et al. concluded that small changes of speed and grade produce differences of energy expenditure that can be accurately measured, which allows for accurate prediction trends in caloric expenditure during walking.

Dill (1964) tested the reliability of the method developed to estimate oxygen cost for both the horizontal component and vertical component of treadmill walking and running. He collected $\dot{V}O_2$ data from a limited sample size which included himself and two other trained males. From this, Dill created a curve which enabled one to estimate the cost of horizontal and grade walking and running. Because of the small sample size and increased chance of error, one should be cautious in using this estimation method. Seven male subjects were then tested at the speed of 188 m/min with the actual values being compared to the predicted values. The average actual $\dot{V}O_2$ was 45.5 ml/kg/min and the predicted, 45.7 ml/kg/min. Dill concluded that this method for estimating oxygen cost was reliable.

The kcal costs of running and walking one mile for men

and women were investigated by Howley and Glover (1974). Eight men and eight women walked at a speed of 82 ± 3 m/min and each ran at a subjectively comfortable speed (men, 195 ± 25 m/min; women, 137 ± 4 m/min). The kcal cost of walking was 1.08 ± 0.06 kcal/kg/mi for men and 1.15 ± 0.08 kcal/kg/mi for women, and the cost of running was 1.57 ± 0.09 kcal/kg/mi for men and 1.73 ± 0.09 kcal/kg/mi. The net kcal cost (difference between resting energy expenditure and submaximal exercise energy expenditure) of walking was 0.76 ± 0.07 kcal/kg/mi for men and 0.83 ± 0.08 kcal/kg/mi for women, and the net cost of running was 1.43 ± 0.08 kcal/kg/mi for men and 1.53 ± 0.09 kcal/kg/mi for women. The one mile run required significantly more kcal than the mile walk for both men and women subjects ($p < 0.001$). The women used significantly more kcal for both the walk and the run ($p < 0.001$), and more kcal/kg for both activities ($p < 0.05$). Howley et al. suggest that the significance may be due to the units used to express the kcal expenditure. He suggested that when the values are expressed per unit of surface area the differences are no longer significant: for walking, men, 29.96 kcal/m², women, 30.74 kcal/m²; for running, 56.61 and 54.08 kcal/m², respectively. It was concluded that running a given distance required more kcal than walking the same distance.

Montoye, Ayen, Nagle, and Howley (1985) investigated

the oxygen requirement for horizontal and grade walking on a treadmill to validate the ACSM (1980) formulas for estimating submaximal oxygen consumption ($\dot{V}O_2$). Male subjects (N=638) walked at 3 mph at 0 percent grade for 3 min; thereafter, the treadmill was raised 3 percent every 3 min with speed maintained while submaximal $\dot{V}O_2$ was measured. The submaximal $\dot{V}O_2$ at 0 percent grade ranged from approximately 15 to 19 ml/kg/min, and grade walking from approximately 17 to 40 ml/kg/min across all grades used. Montoye et al. concluded that the formulas underestimated the submaximal $\dot{V}O_2$ 0.5 ml/kg/min for each year under 18 years of age (only to age 12), but provided reasonable predictions when applied to adult populations as long as the subjects had achieved a $\dot{V}O_2$ steady-rate.

A comparison of the oxygen cost ($\dot{V}O_2$) of running in trained and untrained men and women was studied by Bransford and Howley (1977). The $\dot{V}O_2$ of running was measured in 40 subjects, 10 in each of the following groups: trained men, trained women, untrained men and untrained women. Each subject performed a submaximal test, conducted at varying speeds (trained, 144 to 307 m/min; untrained, 144 to 225 m/min) and 0 percent grade, and a maximal $\dot{V}O_2$ test. Submaximal $\dot{V}O_2$ ranges for trained and untrained men and women were approximately 35 to 60, 28 to 50, 28 to 47 and 32 to 40 ml/kg/min, respectively. Regression lines indicate

that the VO_2 -running speed relationship was linear for each group. The results indicate that VO_2 increases linearly on the treadmill, regardless of sex or training, within the given range of speeds, 140 to 300 m/min.

An earlier study by Mayhew (1977) produced results similar to Mayhew et al. (1979). The subjects were nine trained runners who ran at eight selected speeds ranging from 134 to 295 m/min while VO_2 was measured. All tests were submaximal. Results demonstrated a mean energy expenditure of 0.97 ± 0.07 kcal/kg/km. He noted an optimal running speed for these subjects when VO_2 was expressed relative to body weight. For these subjects, the speed was 11.1 km/hr, which elicited a VO_2 of approximately 192 ml/kg/km. Mayhew concluded that there is apparently a wide variation in the oxygen cost of running in trained runners and suggested that efficiency in the movement was probably the reason.

Another study that involved trained and untrained men and women was conducted by Mayhew, Piper, and Etheridge (1979). The purpose of the study was to measure oxygen cost and energy requirement of these subjects (N=25) during submaximal treadmill running. They were divided into four groups: trained men, trained women, untrained men, and untrained women. Each subject ran for 5 min work periods horizontally at four selected speeds (135, 150, 165, and 180

m/min) with a 10 min rest between each work bout. The range of relative energy cost (kcal/kg/km) was 1.00 ± 0.07 to 1.10 ± 0.08 , with the trained males expending the least, and the untrained females expending the most energy. No significant differences were found among the group energy expenditures. Their results confirm earlier studies that women expended more relative energy than males during running when expressed relative to body weight.

Oxygen Cost of Skiing

Saibene, Cortili, Roi and Colombini (1989) investigated the energy cost of level cross-country skiing using three skiing techniques: double pole, diagonal stride, and skating. The subjects were six skiers of the Italian National Cross-Country Ski Team. Each subject performed a series of 3 to 4 runs at increasing speeds (200, 250, 300, 350, 400, and 425 m/min) while $\dot{V}O_2$ was measured using a portable breathing valve system connected to a 50 L neoprene bag strapped to their back, with 10-20 min rest between each run. The submaximal $\dot{V}O_2$ ranges for double pole, diagonal stride, and skating were approximately 43, 40, and 35 ml/kg/min, respectively. Saibene et al. conclude that in cross-country skiing the skating technique appears to be less expensive in submaximal $\dot{V}O_2$ than double-stride and double-pole technique.

The primary purpose of Hoffman and Clifford's study

(1990) was to compare the oxygen consumption and other physiological responses elicited by the classical (kick double pole and diagonal stride) and skating (V1 skate and marathon skate) techniques while skiing on flat snow at a submaximal speed. The double pole technique was also included in both the classical and skating techniques. Eight male cross-country ski racers who were proficient at each technique were the subjects. Each subject performed six bouts of skiing using five different techniques. Subjects maintained a constant speed of 14.2 km/hr for each technique and performed three laps on a 420 m oval running track. Heart rate was monitored and oxygen uptake measured during the last minute of exercise of each technique using a portable breathing valve system attached to a neoprene bag attached to the skier's back. Mean heart rate responses ranged from 142 to 160 bpm with the skating double pole technique the lowest and the diagonal stride technique the highest. It was found that the diagonal stride technique required the highest oxygen consumption (approximately 48 ml/kg/min), with the V1 skate, marathon skate, and kick double pole techniques needing 16 percent less (approximately 40 ml/kg/min), and the double pole technique needing 26 percent less (approximately 35.5 ml/kg/min). The submaximal $\dot{V}O_2$ values for V1 skate, marathon skate, and kick double pole techniques were significantly different

($p < 0.01$) from the diagonal stride technique. The results indicated that the double pole technique had the greatest economy, and the diagonal stride technique elicited the greatest physiological demands.

Oxygen Cost of Glideboarding

The specificity of bicycle and glideboard exercise for maximal speed skating was evaluated by Kandou, Houtman, Bol, de Boer, de Groot, and van Ingen Schenau (1987). Eight well-trained male speed skaters participated in this study. Subjects performed three maximal exercise tests: one ice speed skating test, one board gliding test and a bicycle ergometer test. Heart rate was monitored and ventilation (V_E), oxygen uptake (V_{O_2}), and respiratory exchange ratio (RER) were measured and determined using a portable, lightweight Douglas bag instrument. Compared to speed skating, cycling produced significantly higher values of oxygen consumption (57.2 ± 4.9 vs 53.9 ± 4.2 ml/kg/min), ventilation (111.3 ± 10.2 vs. 98.8 ± 7.3 L/min) and respiratory exchange ratio (1.18 ± 0.13 vs. 1.03 ± 0.05 L/min). This suggested that cycling produced a different demand on the aerobic metabolism than speed skating. Glideboarding resulted in a significantly higher value of ventilation (110.0 ± 8.6 L/min) than ice speed skating and resulted in a V_{O_2} max value of 55.1 ± 5.5 ml/kg/min. The RER value for glideboarding was 1.03 ± 0.05

L/min which was not significantly different from the ice speed skating. Biomechanically, speed skating and glideboarding had similar hip and knee angles, angular velocities and angular accelerations. The results indicated that glideboard exercise was a more specific training exercise for speed skating than cycling. Kandou et al. suggested that glideboard exercise should be an important part of the off-season training schedule. No other studies were found concerning glideboarding.

Summary

The oxygen cost of other forms of exercise has been studied extensively, whereas glideboarding has not been. The reviewed literature indicated that during exercise, $\dot{V}O_2$ increased as intensity increased and was comparable among the different modes of exercise. No data was found concerning submaximal $\dot{V}O_2$ during glideboard exercise.

Chapter III

Methods

Preliminary Procedures

Subjects

The subjects consisted of 30 males age 19 to 32 years old. Because of the questionable difference in exercise efficiency between males and females, females were excluded from this investigation. Subjects were recruited in the HPER building at the University of Nebraska at Omaha. The subjects had no contraindicated risk factors (e.g., smoker, personal history of heart problems, orthopedic or musculoskeletal joint problems which could be complicated further through participation) and were involved in aerobic activity for the previous three months which increased the probability that they achieved a steady rate at the selected cadences. Subjects had no previous experience at glideboarding. They completed a medical history and an IRB approved informed consent after it had been satisfactorily explained to them. The subjects were also informed that they may withdraw from the investigation at any time under no penalty.

Glideboard

The glideboard was constructed of polyethylene (0.91 x 2.43 m). At each end of the glideboard were permanent stop blocks. The subject began in a slightly crouched position,

pushed off of the stop block with the lateral side of the foot, glided across the board to the opposite stop block, then repeated the action.

All testing occurred in the Exercise Physiology Laboratory of the University of Nebraska at Omaha.

Pre-trial Tests

Subjects were required to perform three practice sessions on the glideboard prior to the day data was collected. In the first practice, the subject glided without the head gear and breathing apparatus. During the second and third practice sessions, the head gear and breathing apparatus were worn while gliding. Subjects glided at least five minutes until they felt comfortable with the action.

Operational Procedures

Pretest

Subjects were required to avoid eating food for four hours prior to testing and to avoid heavy exertion or exercise 12 hours prior to testing. After a description of the test procedure, each subject was weighed to the nearest 0.1 kg and their height measured to the nearest 0.5 cm using a stadiometer. Supine resting heart rate and blood pressure were also obtained.

Heart Rate Monitor

A Polar Vantage heart rate monitor watch was used to determine heart rate while the subject glided at the selected cadences. The subject wore this device strapped to his chest which detected the electrical activity of the left ventricle during depolarization. At the instant of contraction, the device transmitted a signal to the watch which was held by the investigator. The watch then calculated the heart rate in beats/min, which depended upon the elapsed time between successive depolarizations of the left ventricle.

Borg's Rate of Perceived Exertion (RPE) Scale

Borg's 15-point RPE scale was used to determine how strenuous the subjects felt they were working during each glideboarding test. The scale consists of 15 numbers ranging from the number 6 to 20. A verbal description is provided with each odd number pertaining to the difficulty of the task. At the end of each test the subjects immediately related to the investigator how difficult they perceived the test to be.

Metabolic Measurements

The subject was then fitted with an Otis-McKerrow breathing valve held by a head support attached to a Sensormedics MMC metabolic cart for collection of expired air. Before each test the metabolic cart was calibrated with gases of known concentration as explained in the Sensormedics MMC Operating Manual (1986).

Test

The subjects began gliding for 5 to 10 min at a comfortable pace to provide proper warm-up. At the end of the warm-up, the metronome cadence was adjusted to 42, 48, or 54 beats per minute, and the subjects exercised until a steady rate was achieved. Steady rate was defined as oxygen consumption that did not fluctuate more than 50 ml/min between two consecutive minutes after 5 min of exercise. Each stage lasted approximately 7 to 8 min.

The oxygen consumption and RER at the selected cadences were measured on two nonconsecutive days. The slower cadences of 42 and 48 bpm were performed on the same day in the respective order with a recovery period between the two tests. The second test was initiated once the subjects' HR recovered within 5 to 10 bpm of the HR obtained before the first test. The 54 bpm cadence was performed on a separate day with at least 48 hours between testing days and absence of delayed onset of muscle soreness. Ten of the subjects were retested at a later date using the same protocol to determine test-retest reliability.

Statistical Analysis

The mean and standard deviation were calculated for oxygen consumption, energy expenditure, heart rate, rate of perceived exertion, and respiratory exchange ratio at each selected distance. A one-way ANOVA for repeated measures

was used to compare the mean oxygen cost at each distance. Tukey post-hoc tests were then performed to determine if significant differences existed between the cadences. Pearson r and correlated t tests were used to compare the retest scores of the ten subjects to their previous scores. An alpha level of $p=0.05$ was used for the statistical comparisons.

CHAPTER IV

Results and Discussion

Results

Table 1 describes the physical characteristics of the subjects tested in this study. Table 2 displays the oxygen cost, HR, energy expenditure, RER, and RPE during glideboard exercise at the cadences of 42, 48, and 54 bpm. The $\dot{V}O_2$ means were 1.91, 2.16, and 2.56 L/min at the respective cadences. In relation to body weight, the respective $\dot{V}O_2$ means were 23.6, 26.7, and 31.8 ml/kg/min. The obtained heart rate means were 120.2, 140.6, and 155.3 bpm, respectively. Respective mean RER values were 0.89, 0.90, and 0.93. Respective mean Borg Scale RPE values were 10, 12.2, and 13.6. The energy expenditures for the respective cadences were 9.3, 10.6, and 12.6 kcal/min. The mean differences among the variables were compared by using a one-way ANOVA for repeated measures and Tukey's post-hoc test. All means were significantly different ($p < 0.05$).

Table 3 describes the test-retest reliability of scores for 10 selected subjects. Pearson correlation coefficients between test and retest $\dot{V}O_2$ values were $r=0.83$, 0.94 , and 0.93 at the respective cadences of 42, 48, and 54 bpm. All r values were significant ($p < 0.05$). Correlated t test values indicated that the difference between test-retest $\dot{V}O_2$ values was not significant ($p > 0.05$).

Table 1
Descriptive Data of Subjects, (N=30)

Variable	M	SD
Age, yr	24.5	3.5
Height, cm	178.7	6.68
Weight, kg	81.2	11.77

Table 2
Experimental Data at Three Different Cadences.

Variable	42 b/min		48 b/min		54 b/min		F
	M	SD	M	SD	M	SD	
VO ₂ , L/min	1.91	0.26	2.16	0.34	2.56	0.42	134.1*
VO ₂ , ml/kg/min	23.6	2.86	26.7	2.93	31.8	2.91	178.7*
HR, bpm	120.2	26.81	140.6	12.68	155.3	12.88	38.2*
RER	0.89	0.04	0.90	0.04	0.93	0.04	14.4*
RPE	10.0	2.31	12.2	1.29	13.6	1.73	78.9*
Kcal/min	9.3	1.29	10.6	1.73	12.6	2.18	106.1*

* ($p < 0.05$) All means are significantly different for each variable.

Table 3
Test-Retest Reliability Data, (N=10)

Variable	Difference		r*	t
	M	SD		
V02-42, L/min	-0.04	0.23	0.83	-0.55
V02-42, ml/kg/min	-0.61	2.58	0.83	-0.75
V02-48, L/min	0.05	0.15	0.94	0.98
V02-48, ml/kg/min	0.51	2.04	0.94	0.79
V02-54, L/min	-0.06	0.18	0.93	-1.02
V02-54, ml/kg/min	-0.57	2.26	0.93	-0.80

* All r values, $p < 0.05$. All t values, $p > 0.05$.

Discussion

The research hypothesis was that there was significant difference in the oxygen cost, energy expenditure, and heart rate among the various cadences. The results indicated that this was true.

Oxygen Cost

The oxygen cost of glideboarding in this study was 23.6, 26.7, and 31.8 ml/kg/min at the respective cadences of 42, 48, and 54 bpm. In comparison to other forms of exercise, glideboarding requires a similar oxygen cost. According to the ACSM Guidelines (1991), walking at 3 to 3.75 mph at a 7.5 to 10 percent grade requires 22.4 to 31.8 ml/kg/min. Erickson et al. (1945) found that the oxygen cost of walking at 3.5 mph/10 percent grade was 25.97 ml/kg/min. This value falls into the oxygen cost range of glideboarding at all cadences of this study, but was more commonly associated with the slower cadences. Montoye et al. (1985) studied the oxygen cost of walking 3 mph at varying grades. Submaximal $\dot{V}O_2$ at 0 percent grade was approximately 15 to 19 ml/kg/min and grade walking approximately 17 to 40 ml/kg/min. When compared to glideboard exercise, 0 percent grade walking did not elicit as great a response as glideboarding at 42 bpm, but walking between 9 and 15 percent grade elicited responses similar to this study.

Bransford and Howley (1977) measured the oxygen cost of trained and untrained runners at various speeds and 0 percent grade. The trained and untrained males elicited an oxygen cost ranging from 35 to 60 and 28 to 47 ml/kg/min, respectively. In comparison to glideboard exercise, these values indicate that running is more intense. The lowest running $\dot{V}O_2$ was comparable to the 48 and 54 bpm respective test values of 26.7 and 31.8 ml/kg/min. It was speculated that the glideboard $\dot{V}O_2$ was less because vertical movement of the center of mass is less present in the activity. Similar to walking, one foot is usually in contact with the surface during glideboard exercise. This may explain why the $\dot{V}O_2$ of the more intense cadences are similar only to the running speed of 5 mph/0 percent grade.

Mayhew (1977) studied the oxygen cost of running at various speeds and 0 percent grade. His results indicated that running at 6 mph elicited a $\dot{V}O_2$ of 30.1 ml/kg/min. In this study submaximal $\dot{V}O_2$ at 54 bpm was 31.8 ml/kg/min. Therefore, running at 6 mph/0 percent grade appears to elicit a slightly lower $\dot{V}O_2$ than glideboarding at 54 bpm.

Lang et al. (1992) measured $\dot{V}O_2$ during submaximal exercise on a cycle ergometer. The values were 0.94, 1.23, 1.55, 1.93, and 2.35 L/min at the respective workloads of 30, 60, 90, 120, and 150 W. The latter two workloads produced the most comparable results to glideboard $\dot{V}O_2$ which

were 1.91, 2.16, and 2.56 L/min at the respective cadences of 42, 48, and 54 bpm.

Using the ACSM Guidelines (1991) cycling resistances can be adjusted to elicit oxygen costs comparable to glideboarding at the respective cadences and distance of this study. For example, a 70 kg man would set the resistance at 675 to 963 kgm/min to achieve similar oxygen costs of glideboarding at the three cadences. Refer to Table 4 for workloads of selected exercises that produce oxygen costs comparable to glideboard exercise at the cadences of 42, 48, and 54 bpm.

Erickson et al. (1945) assessed the energy expenditure of walking at 16 different combinations of speeds and grades covering the range from 2.5 to 4.0 mph at 0 to 10 percent grade. The majority of walking speeds and grades did not involve oxygen consumption that was comparable to the energy expenditure of glideboard exercise, except for the workloads of 3 mph/10 percent grade and 4 mph with a 6 to 10 percent grade which produced comparable $\dot{V}O_2$ values.

Energy Expenditure

ACSM Guidelines (1991) state that aerobic exercise should be performed 15 to 60 min, between 40 and 85 percent of maximal $\dot{V}O_2$, which corresponds to 55 to 90 percent of maximal heart rate, at least three times a week, to maintain or improve functional capacity. As illustrated earlier,

Table 4
Selected Exercises and V02 for 70 kg Male

Glideboard	Selected Exercise/
Cadence	Workload
42 bpm -6.7 METs	Walk - 3 to 3.5 mph/7.5% grade 4 mph/5% grade Cycle - 675 kgm/min
48 bpm -7.6 METs	Walk - 3 mph/10% grade 3.75 mph/7.5% grade Cycle - 785 kgm/min Run - 5 mph/0% grade
54 bpm -9.1 METs	Walk - 3.75 mph/10% grade Cycle - 963 kgm/min Run - 5 mph/0 to 2.5% grade

the oxygen cost of glideboarding is sufficient for maintenance or improvement of functional capacity. Individuals with a low level of fitness could improve or maintain functional capacity glideboarding at the cadences of 42 and 48 bpm. For highly fit individuals, the oxygen cost is too low (31.8 ml/kg/min at 54 bpm) for either maintenance or improvement. Using the mean oxygen cost values (L/min) of the subjects in this study, the energy expenditure of glideboarding for 20 to 30 min at the selected cadences would range from 186 to 378 kcal/min.

ACSM Guidelines (1991) instruct that for optimal weight loss an exercise program should provide a daily caloric expenditure of 300 or more kcal. Because the energy expenditure during glideboarding meets this criterium, it is logical that this activity could be used as a training modality in a weight loss program.

Heart Rate, RPE, and RER

HR, RPE, and RER followed the logical pattern of increasing from the slower to the faster cadences. As the demand for oxygen increased, the HR also increased to allow more oxygen to be transported to the working muscles. The RER values of 0.89, 0.90, and 0.93 at the respected cadences of 42, 48, and 54 bpm indicated that as energy requirements increased, so did carbohydrate metabolism. With one of the by-products of anaerobic carbohydrate metabolism being

lactic acid (LA), it was suggested that increased LA in the blood resulted in a greater state of fatigue, which would account for a higher RPE rating. At the cadences of 48 and 54 bpm the majority of subjects had reached lactate threshold according to RPE scores. RPE of 13 to 16 is the common rating when lactate threshold is reached (ACSM, 1991), which is between 55 and 65 percent of maximal $\dot{V}O_2$ for most individuals (McArdle, Katch, & Katch, 1991).

Reliability

Test-retest data indicated that the scores were highly reproduceable, as indicated by the strong Pearson r and the non-significant correlated t test value at each cadence. Since glideboard exercise was a novel activity for all of the subjects, high reliability was not expected. Also, there was some variability in some of the subjects' technique between test and retest. The two most common changes noted from observation were added, or exaggerated, arm swing, and increased knee flexion after the gliding phase prior to pushing away from the block. Initially, it would seem the increased use of musculature may have increased $\dot{V}O_2$, but it also may have improved efficiency by increasing the amount of mass moving in one direction, consequently, reducing the amount of force needed to start movement in the intended direction, resulting in a reduced $\dot{V}O_2$. Overall, it would seem that the scores are highly

reproduceable at these cadences.

CHAPTER V

Summary, Conclusions, and Recommendations

Summary

The purpose of this study was to investigate the oxygen cost of glideboarding at selected cadences and distance. The subjects (N=30) were males, 19 to 32 years old. The protocol involved the subjects gliding 1.73 m at the selected cadences of 42, 48, and 54 bpm while expired air was collected and analyzed. Ten of the subjects were retested for reliability of the testing procedure. A statistical analyses utilizing mean, standard deviation, a one-way ANOVA for repeated measures, and Tukey's post-hoc tests were performed. Test-retest reliability data were analyzed using a Pearson correlation coefficient and correlated t test.

Analyses indicated significant ($p < 0.05$) differences among the selected cadences for all of the variables. For VO_2 (L/min and ml/kg/min), HR, and kcal/min, the largest difference was between the 42 and 54 bpm cadence, and the second largest and smallest difference between 48 and 54 bpm and 42 and 48 bpm, respectively. VO_2 (L/min) was 1.91, 2.16, and 2.56, respectively. VO_2 (ml/kg/min) was 23.6, 26.7, and 31.8, respectively. Respective HRs were 120, 141, and 155 bpm. Respective kcal/min were 9.3, 10.6, and 12.6.

Reliability data indicated a strong relationship

($p < 0.05$) between test-retest scores with respective r 's of 0.83, 0.94, and 0.93. All t values showed no significant ($p > 0.05$) difference between test-retest mean scores.

Conclusions

Based on the findings of this study, the conclusion obtained is that there is a significant difference in V_{O_2} among the selected cadences at 1.73 m. The energy expenditure is comparable to walking 3 mph/7 percent grade to 3.75 mph/10 percent grade; cycling 675 to 963 kgm/min; and running 5 mph/0 to 2.5 percent grade. Therefore, the oxygen cost is at a level in which an individual can use the glideboard in a weight loss or fitness program (ACSM, 1991).

Recommendations

The subjects in this investigation were young, healthy males. Other populations, i.e., women, elderly, children, should be tested to gather more data on the oxygen cost of glideboarding and to see what the differences are, if any, in efficiency. A recommendation for further study would be to measure oxygen cost at other combinations of distance and cadence. Another recommendation is to investigate the friction of the different glideboard materials and to what extent it affects V_{O_2} .

As a result of this investigation data are now available concerning the submaximal oxygen cost of glideboarding. More information needs to be collected on

the energy expenditure of glideboarding, so that appropriate training programs or exercise prescriptions may be developed to meet the goals of an individual interested in using this mode of training.

Appendix I
Informed Consent

**Adult Informed Consent Form
IRB #203-93**

**OXYGEN COST OF GLIDEBOARDING AT SELECTED CADENCES AND
DISTANCE**

Invitation To Participate

You are invited to participate in this research study. The following information is provided in order to help you to make an informed decision whether or not to participate. If you have any questions please do not hesitate to ask.

Basis For Subject Selection

You are being asked to participate in this study because you are a healthy male between the ages of 19 and 35. You may participate only if you are a nonsmoker, have no cardiovascular, metabolic, and/or orthopedic or musculoskeletal disorders, no glideboard exercise experience, and have been aerobically active for the previous three months.

Purpose Of The Study

The purpose of this study is to determine the oxygen cost during glideboard exercise at the cadences of 42, 48, and 54 beats per minute. This will help us know the energy expended during glideboard exercise.

Explanation Of Procedures

Prior to participation in the study, you will be asked to fill out a medical history form and read and sign a consent

form. Once it has been determined that you have met the criteria, you will be scheduled for three practice sessions to be held in the Exercise Physiology Laboratory at the University of Nebraska at Omaha. Each session will last approximately one hour. After the practice sessions, a test day will be scheduled. Prior to any testing, measurements of your height, weight, and resting heart rate and blood pressure will be made. Next, you will be asked to perform glideboard exercise while the oxygen cost is measured. You will breathe through a mouthpiece supported by head gear and attached to a metabolic cart. On one day you will be asked to glide at a cadence of 42 beats per minute for about 5 to 6 minutes. After a 10 to 20 minute rest period, you will then glide at a cadence of 48 beats per minute. On a different testing day, you will be asked to glide at a cadence of 54 beats per minute. Cadence will be dictated by a metronome. Each test session will have a duration of at least five minutes. The distance for glideboard exercise will be set at 1.73 meters (5.7 feet). Heart rate will be monitored using a heart rate monitor watch. You will be given at least two days rest between testing days until muscle soreness is absent from the previous testing day. In order to obtain accurate test results you will be asked to refrain from eating for at least four hours before testing, and not to exercise or perform vigorous activity 12

hours prior to participating.

Potential Risks And Discomforts

Possible risks associated with this study include and are not limited to heart attack, abnormal heart rhythms, abnormal blood pressure, stroke, shortness of breath, dizziness, reduced coordination and muscle soreness. The risks of these occurring in healthy, younger subjects is very low. Most of the discomforts are relatively short lived.

Potential Benefits To The Subject

You will gain no benefits from participating in this study.

Potential Benefits To Society

Society would benefit by obtaining data that pertains to oxygen cost of glideboard exercise at these selected cadences. By knowing the energy expenditure of glideboard exercise at these cadences and distance, an exercise prescription may be developed for proper weight loss or management.

Financial Obligations

The tests will be provided to you free of charge.

Emergency Care And Compensation In Case Of Injury

In the unlikely event that you should suffer an injury as a direct consequence of the research procedures described above, the emergency medical care required to treat the injury will be provided at the University of Nebraska at

no expense to you providing that the cost of such medical care is not reimbursable through your health insurance. However, no additional compensation for physical care, hospitalization, loss of income, pain, suffering, or any other form of compensation will be provided. None of the above shall be construed as a waiver of any legal rights or redress you may have.

Assurance Of Confidentiality

Information obtained from you in this study will be treated confidentially. Your names will not be used in the publishing of the results of this study. Only grouped data will be reported.

Rights of Research Subjects

Your rights as a research subject have been explained to you. If you have any additional questions concerning your rights you may contact the University of Nebraska Institutional Review Board (IRB), telephone 402/559-6463.

Voluntary Participation And Withdrawal

Participation is voluntary. Your decision whether or not to participate will not affect your present or future relationship with the University of Nebraska at Omaha. If you decide to participate, you are free to withdraw.

Documentation Of Informed Consent

YOU ARE VOLUNTARILY MAKING A DECISION WHETHER OR NOT TO PARTICIPATE IN THIS RESEARCH STUDY. YOUR SIGNATURE

CERTIFIES THAT THE CONTENT AND MEANING OF THE INFORMATION ON THIS CONSENT FORM HAVE BEEN FULLY EXPLAINED TO YOU AND THAT YOU HAVE DECIDED TO PARTICIPATE HAVING READ AND UNDERSTOOD THE INFORMATION PRESENTED. YOUR SIGNATURE ALSO CERTIFIES THAT YOU HAVE HAD ALL YOUR QUESTIONS ANSWERED TO YOUR SATISFACTION. IF YOU THINK OF ANY ADDITIONAL QUESTIONS DURING THIS STUDY PLEASE CONTACT THE INVESTIGATOR(S). YOU WILL BE GIVEN A COPY OF THIS CONSENT FORM TO KEEP.

Signature of Subject

Date

MY SIGNATURE AS WITNESS CERTIFIES THAT THE SUBJECT SIGNED THIS CONSENT FORM IN MY PRESENCE AS HIS/HER VOLUNTARY ACT AND DEED.

Signature of Witness

Date

IN MY JUDGEMENT THE SUBJECT IS VOLUNTARILY AND KNOWINGLY GIVING INFORMED CONSENT AND POSSESSES THE LEGAL CAPACITY TO GIVE INFORMED CONSENT TO PARTICIPATE IN THIS RESEARCH STUDY.

Signature of Investigator

Date

Investigators

Randy Tolle, M.S.	554-2670
Richard Latin, Ph.D	554-2670
Kris E. Berg, Ed.D	554-2670
Wayne Stuberg, Ph.D	559-5720

Consent Form IRB Approved March 5, 1993

Appendix II**IRB Proposal**

Oxygen Cost of Glideboarding at Selected Cadences and Distance

I. Purpose Of The Study

The purpose of this study is to measure how much oxygen is consumed when exercising on a glideboard. Through measurement of oxygen consumption (V_{O_2}) during exercise the amount of energy expended can be determined.

II. Background

Numerous studies have collected data on V_{O_2} , energy expenditure (kcal), and heart rate for different modes of exercising, such as skiing (1), cycling (2), running (3), and walking (4). Currently no information can be found in the research literature that has explored V_{O_2} , energy expenditure, and heart rate for glideboard exercise, thus the purpose of this study. By knowing the energy expenditure of glideboard exercise at these selected cadences and distance, it may be incorporated into an exercise prescription developed for proper weight loss.

III. Characteristics Of Subject Population

- A. Age Range. Subjects will be between 19 and 35 years old.
- B. Sex. Male subjects will be used in this study.
- C. Number. 50 subjects will be used in this study.

D. Inclusion Criteria. Subjects will need to be non-smokers, free from major cardiovascular risk factors, and orthopedic and metabolic disorders, have no previous glideboarding experience, and aerobically active for the previous three months.

E. Exclusion Criteria. Subjects not meeting the above criteria will be excluded from participation.

F. Vulnerable Subjects. N/A

IV. Method Of Subject Selection

Volunteer subjects will be recruited from classes offered in the School of HPER. Solicitations for participation will also be placed in the School's physical fitness facilities.

V. Study Site

The study site will be located at the School of HPER at UNO in the Exercise Physiology Laboratory.

VI. Methods And Procedures Applied To Human Subjects

Pre-trial Tests. Subjects will be required to perform three practice sessions on the glideboard prior to the day data is collected. In the first practice, the subjects will glide without head gear and breathing apparatus. During the second and third practice sessions, the head gear and breathing apparatus will be worn while gliding. Gliding

duration will be no less than five minutes each practice session.

Pretest. Subjects will be required to avoid eating food for four hours prior to testing and to avoid heavy exertion or exercise 12 hours prior to testing. After a description of the test procedure and signing of an informed consent, each subject will be weighed to the nearest 0.1 kg and their height measured to the nearest 0.5 cm using a stadiometer.

Heart Rate Monitor. A Polar Vantage heart rate monitor watch will be used to determine heart rate while the subjects glide at the selected cadences. The subjects will wear this device strapped to their chest which detects the electrical activity of left ventricular depolarization. The device transmits a signal to the watch that is held by the investigator and the heart rate is displayed on the watch face.

Metabolic Measurements. The subject will be fitted with an Otis-McKerrow breathing valve held by a head support attached to a SensorMedics MMC metabolic cart for collection of expired air. Before each test the metabolic cart will be calibrated with gases of known concentration as explained in the SensorMedics MMC Operating Manual (5).

Test. The subjects will begin gliding for 5-10 min at a comfortable pace to provide proper warm-up. At the end of the warm-up, the metronome cadence will be adjusted to 35, 45, or 55 beats per minute, and the subjects will exercise until a steady rate is achieved. Steady rate will be defined as the absolute difference of oxygen consumption no greater than 50 ml/min for two consecutive minutes. Gliding distance will be set at 1.52 m.

Order of Tested Cadences. The oxygen consumption at the selected cadences will be measured on two nonconsecutive days. The cadences used will be assigned randomly with the 35 and 45 beats per minute tests performed on the same day in random order. The 55 beats per minute cadence will be performed on a separate day with at least 48 hours between testing days and an absence of delayed onset muscle soreness.

Test-retest Reliability. Ten of the subjects will be retested at a later date using the same protocol to determine test-retest reliability.

VII. Potential Risks

A. Risk Classification. The subjects will be performing moderate intensity exercise (below or at 85 percent of maximal heart rate), and are

younger, and appear to be healthy. Therefore, the risk classification should be minimal.

- B. Potential Risks. Possible risks associated with submaximal exercise tests include and are not limited to heart attack, abnormal heart rhythms, abnormal blood pressure, stroke, shortness of breath, dizziness, reduced coordination and muscle soreness. The risks of these occurring in healthy, younger subjects is very low. Most of the discomforts are relatively short lived.

VIII. Protection Against Risks

The exercise will be performed at a submaximal intensity. Because the subjects are young, healthy, and previously active for at least the previous three months, the chance of injury or harm will be minimal. Also, the primary investigator is certified in cardiopulmonary resuscitation.

IX. Potential Benefits To The Subject

The subjects will gain no benefits from participating in this study.

X. Potential Benefits To Society

Society would benefit by obtaining data that pertains to oxygen consumption of glideboard exercise at these selected cadences. By knowing the energy expenditure of glideboarding at these cadences and distance, an

exercise prescription may be developed for proper weight loss or management. Also, due to the specificity of the movement, the glideboard could be an excellent training modality for individuals involved in skating activities, who may wish to maintain or increase cardiovascular endurance.

XI. Therapeutic Alternatives

This is a non-therapeutic study.

XII. Compensation For Participation

The subjects will not receive any financial compensation for participating in this study.

XIII. Confidentiality

Information obtained in this study will be treated confidentially. The subjects' names will not be used in the publishing of the results of this study. Only grouped data will be reported.

XIV. Information Purposely Withheld

No information will be purposely withheld from the subjects.

XV. Informed Consent

Most of the participants in this study will be university students or faculty/staff, therefore, it is assumed that they will be able to comprehend the informed consent. The consent form will be given to and obtained by the investigator prior to any

testing. Once consent is obtained the investigator will ask the individual several questions about the study to verify that he understood the form. Also, the investigator will answer any questions the subject may have.

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