ABSTRACT

SUSCHA, R. G. A comparison of heart rate and oxygen uptake on the NordicTrack Achiever and the NordiCare Strider at equivalent work settings. MS in Adult Fitness/Cardiac Rehabilitation, 1994, 87pp. (J. Porcari)

Metabolic and physiologic responses to arm and leg exercise on the NordiCare Strider (NCS) and the NordicTrack Achiever (NTA) were used to determine differences between the devices. Twenty-four healthy male Ss, 18 to 40 years of age were equally matched to 8 random testing combinations varying in arm and leg, and device order. Three, 20 min practice sessions preceded 2 testing sessions to ensure minimum efficiency in the use of the NTA and NCS. The Ss exercised for 16 min through 4 stages during a leg test, and followed with a 20 min, 5 stage arm test after a 10 min rest period. A constant cadence of 60 cycles/min was maintained with work rate progressively increasing each stage through applied arm and leg resistance. The variables of absolute (L/min) and relative (ml/kg/min) VO_2, V_E (BTPS) (L/min), RER, HR (bpm), and RPE were measured and recorded at all stages. Paired t-tests were performed for all variables between the NCS and NTA during arm and leg testing. The results indicated significantly ($p < .05$) higher absolute (L/min) and relative (ml/kg/min) VO_2, and V_E response to arm exercise using the NCS at all stages, and significantly ($p < .05$) higher RER, HR, and RPE response except for stage 1. The differences were present because the arm resistance for the NCS was measured as being higher than what was indicated by the indicator dial. There was no significant ($p > .05$) difference in the responses of RER, HR, and RPE at all stages between the NCS and the NTA during leg exercise, and no significant ($p > .05$) difference in the absolute (L/min) and relative (ml/kg/min) VO_2, and V_E responses, except for stage 2. The lack of differences during leg exercise between the NCS and the NTA can be attributed to the indicator settings for both devices accurately indicating measured resistances. The measured differences in forward leg resistance between the NCS and the NTA was apparently insignificant.

A COMPARISON OF HEART RATE AND OXYGEN UPTAKE ON THE NORDICTRACK ACHIEVER AND THE NORDICARE STRIDER AT EQUIVALENT WORK SETTINGS

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CHAPTER I

INTRODUCTION

The aerobic demands and training benefits of cross-country skiing are well documented (Bergh, 1982, 1987; Kelly, 1990; Millerhagen, Kelly, & Murphy, 1983). Cross-country skiing is considered a highly aerobic exercise because of the involvement of the arms and legs. Because of the known cardiovascular benefits of cross-country skiing, a simulated ski machine was developed by NordicTrack (NordicTrack Inc., 1989, 1991). With the NordicTrack, the average exercising consumer, as well as the avid cross-country ski enthusiast can reap cardiovascular benefits at home or at a health club.

The NordicTrack, which was the first ski ergometer on the market (NordicTrack Inc., 1989, 1991) has been updated from its original model to be more durable and marketable. The most recent NordicTrack model is the NordiCare Strider (NCS) (see Figure 1). It was primarily developed and marketed for cardiac rehabilitation facilities and corporate fitness centers. Metabolic studies have been done on the NordicTrack Pro and compared it to other cardiovascular exercise modalities (Allen & Goldberg, 1986a, 1986b; Thomas, Feiock, & Araujo, 1989). These studies concluded that heart rate response and oxygen uptake when using the NordicTrack

Pro are similar or superior to other common forms of aerobic exercise. Studies on the new model, the NCS, and its comparison to the NordicTrack Achiever (NTA) (see Figure 2), which is mechanically similar to the NordicTrack Pro, or to other exercise modalities have not yet been done.

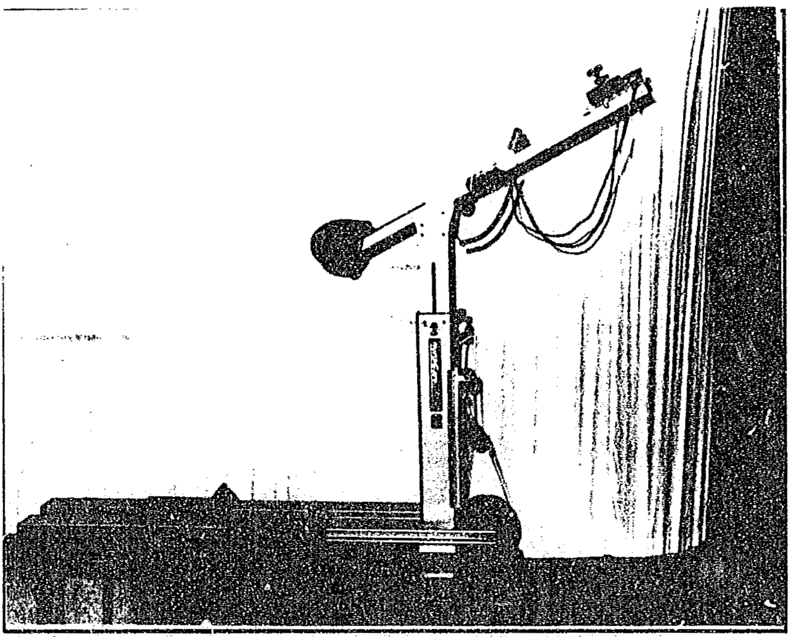

Figure 1. The NordiCare Strider is the most recent NordicTrack ski machine model, and primarily developed for rehabilitation facilities and fitness centers.

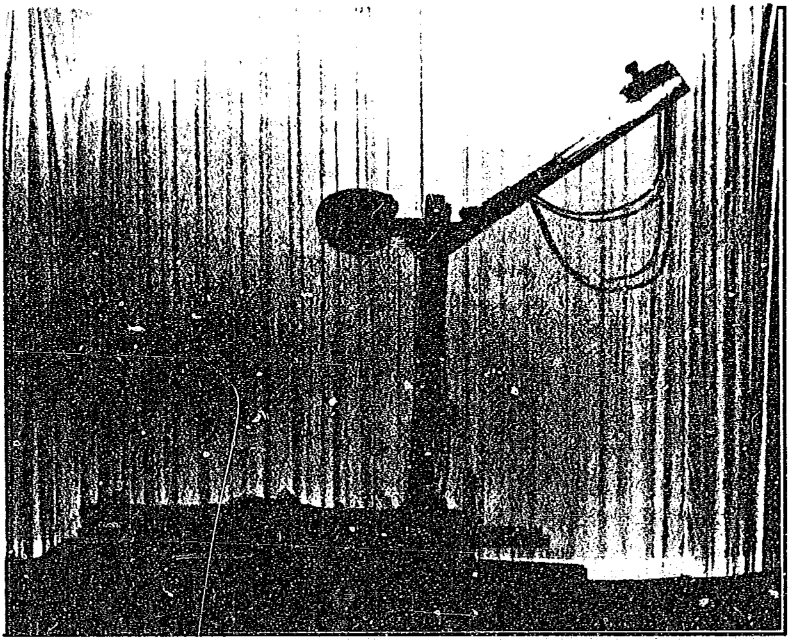

Figure 2. The NordicTrack Achiever showing the original design of the NordicTrack ski machine.

Need for the Study

The cardiovascular benefits of arm-only, leg-only, or combined arm and leg exercise on the NordicTrack Pro have been previously studied (Allen & Goldberg, 1986a, 1986b; Goss et al., 1989; Jacobsen, Leon, Wang, Serfass, & Hunninghake 1986; Tesch, 1988; Thetford, 1984). Also, comparison studies of the NordicTrack Pro to other forms of exercise have shown NordicTrack exercise to be greater than or equivalent in terms of the cardiovascular response to exercise (Allen & Goldberg, 1986a, 1986b; Thomas et al., 1989). These research results concluded that a beneficial cardiovascular response occurs when using the NordicTrack Pro, and when it was compared to other aerobic modalities, but no data could be found comparing the NTA and the NCS.

The NCS has been promoted for use in cardiac rehabilitation programs and fitness facilities because of its increased stability, low skill requirement, and operational safety. To obtain these added benefits, the mechanical design of the new model (the NCS) has changed from previous models such as the NTA, but the result was increased forward leg resistance (see Appendix D). The information obtained from studies done on the NordicTrack ski machines with the original design such as the NordicTrack Pro and the NTA, has been unfoundedly used as normative values of what would be expected when using the NCS. Without accurate or reliable information on expected energy cost and heart rate when using an exercise device such as the NCS, the development and transfer of a workload based exercise prescription would be inappropriate. Because the NCS and the NTA were mechanically different, a comparison between the two similar devices was needed to determine similarities or differences before one may accurately develop an appropriate exercise prescription using workload settings.

Since the NordicTrack models have changed and no quantifiable comparison exists between any of the models, it was the intent of this study to compare and determine any differences in the NTA and the NCS at equivalent work settings.

Statement of the Problem

The purpose of this study was to compare the metabolic and physiologic responses of exercise on the NCS and the NTA at equivalent work settings.

Hypotheses

The following null hypotheses were tested at the $p < .05$ level of significance:

1. There will be no significant differences in the VO_2 expressed in absolute (L/min) or relative (ml/kg/min) terms when arm or leg exercising on the NTA and the NCS at equivalent work settings.
2. There will be no significant differences in the ventilation (V_E) response to arm or leg exercise on the NTA and the NCS at equivalent work settings.
3. There will be no significant differences in the respiratory exchange ratio (RER) when arm or leg exercising on the NTA and the NCS at equivalent work settings.
4. There will be no significant differences in the heart rate (HR) when arm or leg exercising on the NTA and the NCS at equivalent work settings.
5. There will be no significant differences in the rating of perceived exertion (RPE) when arm or leg exercising on the NTA and the NCS at equivalent work settings.

Assumptions

The following assumptions were made for this study:

1. It was assumed that the subjects were apparently healthy and free of pathological conditions which would impair performance.
2. It was assumed that the calibration technique for checking resistance at apparently equivalent workloads on the two ski machines was valid and reliable.
3. It was assumed that the subjects did not eat, use tobacco, or consume alcoholic or caffeinated beverages within 3 hours of the testing.
4. It was assumed that the fixed cadence was maintained during the arm and leg tests.

Delimitations

The following delimitations were made in this study:

1. All the subjects were healthy male volunteers between the ages of 18 and 40 years.
2. All the subjects were required to participate in three practice sessions.

Limitations

The following limitations were recognized in this study:

1. The subjects were volunteers; therefore, they were not a truly random sampling of the population.
2. Since only male subjects were tested, the results may not apply to women.

3. Only a minimal level of efficiency for NordicTrack skiing of each subject was expected.

Definition of Terms

The following terms were used in this study:

Cadence - the rhythmical rate of synchronous arm and leg movements as paced by a metronome.

Heart Rate (HR) - the rate of myocardial contraction as measured by the number of heart beats in 1 minute.

Movement Cycle - the complete movement on the NordicTrack machine measured in cycles/minute. A cycle begins with the right arm and left leg in the forward position, and the left arm and right leg in the back position. The right arm and left leg are then drawn backward simultaneously with the forward movement of the left arm and right leg. The reverse action then follows reestablishing the original position. This constitutes one complete cycle or two strokes (McGinnis & Dillman, 1989).

Oxygen Consumption (VO_2) - the volume of oxygen consumed per minute which may be expressed in absolute (L/min) and relative (ml/kg/min) terms (Fox, Bowers, & Foss, 1989).

Rating of Perceived Exertion (RPE) - a subjective rating scale where by the subject rates the overall intensity of the exercise being performed (Borg, 1973).

Respiratory Exchange Ratio (RER) - the ratio of the volume of carbon dioxide produced (VCO_2) to the volume of oxygen consumed (VO_2) during a given time interval (Fox et al., 1989).

Steady-State - the time period during which the consumption of oxygen is at a relatively constant value. Usually, steady-state is reached within 3-4 minutes after work begins or increases (Fox et al., 1989).

Stroke - the synchronous movement of the arm and leg providing the backward thrust to counteract and propel the flywheel against resistance. One stroke is equal to one half of a cycle movement and is measured in strokes/minute.

Ventilation (V_E) - the volume of air expired in one minute as determined by the measured values of depth (tidal volume) and rate (frequency) of breathing (Fox et al., 1989).

CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

In order to cover pertinent background information, the following review of literature was developed and categorized into the following order: NordicTrack models and NordicTrack research.

NordicTrack Models

The general NordicTrack design of the flywheel with its one-way clutch mechanism and upper-body exerciser has not changed. The NordicTrack line ranges from the home marketed models to the newly marketed rehabilitative and fitness center models. The major differences between the NTA and the NCS besides aesthetics include the means of adjusting elevation, the mechanism for setting arm and leg resistance, and foot glides for the NCS instead of wooden skis as for the NTA. For the present study, the mechanical differences noted between the NCS and the NTA were the drive system which incorporates the wooden skis or foot glides, the drive rollers, the flywheel, and the drag assembly, and the arm exerciser resistance system.

The Mechanical Drive Systems

The mechanical drive system begins with where the feet are placed on the ski machine. Figure 3 shows the NTA having wooden skis that ride over a rubber drive roller to drive the flywheel. The NCS has foot glides with ball

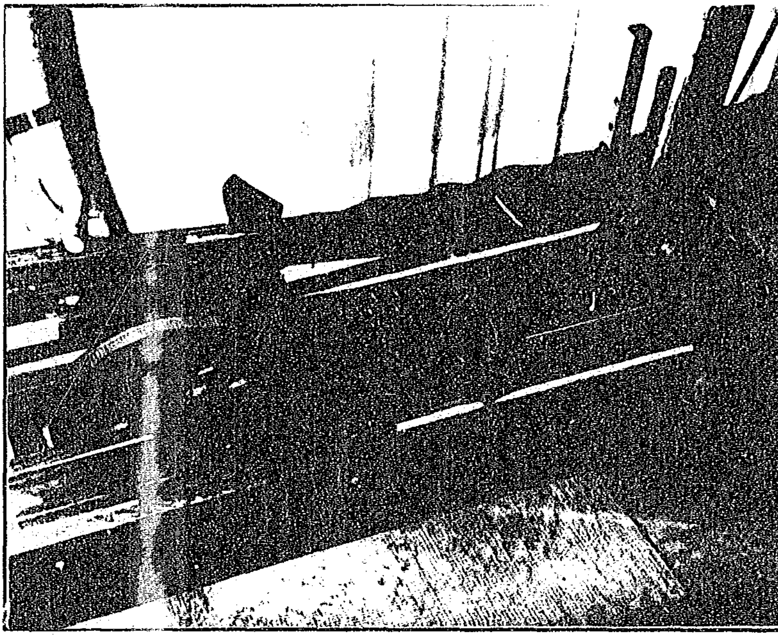

Figure 3. The wooden skis, drive roller, and flywheel of the NordicTrack Achiever.

bearing wheels which roll along guide rails and drive the flywheel by way of a glide strap (see Figure 4). The glide strap is attached to the underside of the foot glide and wraps around a rear roller and the front one-way clutch roller which drives the flywheel (see Figure 5). It should be noted that the one-way clutch rollers (i.e. drive rollers) of both the NTA and the NCS are similar to a ratchet mechanism. The drive rollers are attached to the

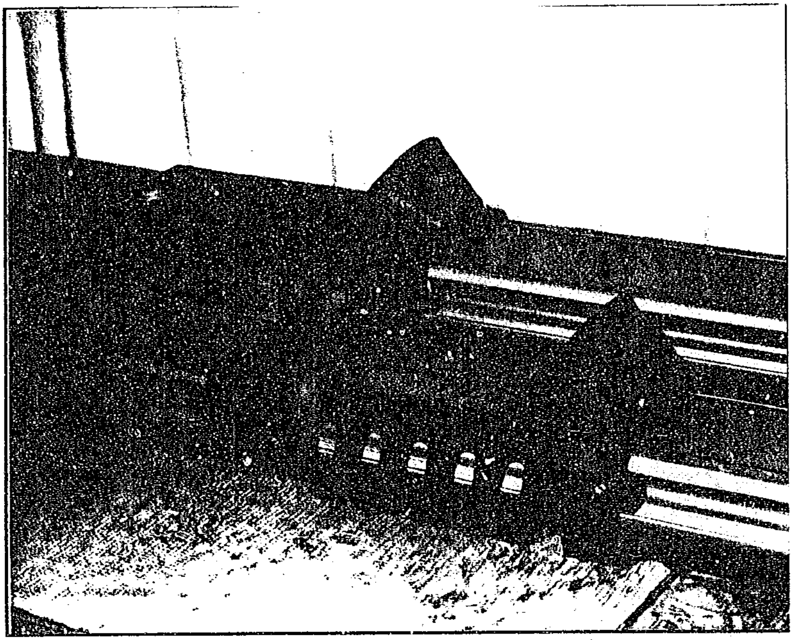

Figure 4. The foot glides, ball bearing wheels, and guide rails of the NordiCare Strider.

same axle as the flywheel and transmit the rotational force to the axle in only one direction (see Figures 5 and 6). Thus, the flywheel turns in only one direction with each backward leg stroke.

The drag assemblies of both the NTA and the NCS function on the principle of friction. As the tension knob is turned to tighten or shorten the friction strap around the flywheel, a resistance is applied to the flywheel and resists the backward leg stroke of an individual. This drag system is very similar to the functioning of a Monarck bicycle ergometer.

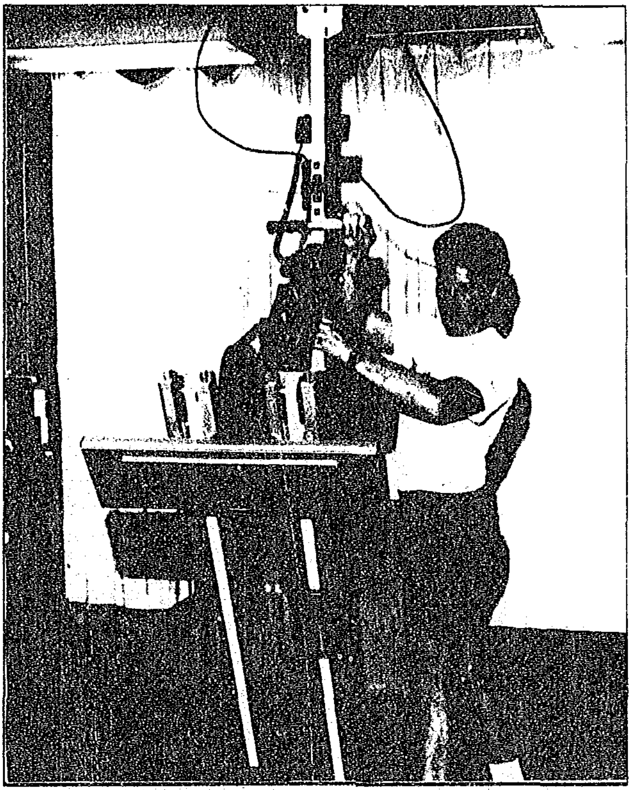

Figure 5. The underside of the NordiCare Strider showing the flywheel, drive rollers, glide strap, and drag assembly.

The circumferences of the drive rollers and the flywheels are different between the NCS and the NTA. Also, the ratio of the drive roller circumference to the flywheel circumference is different between the two devices. This means the mechanical transfer of resistance to the flywheel and to an individual's legs is different when the tension knob is adjusted. Furthermore, the revolutions per minute

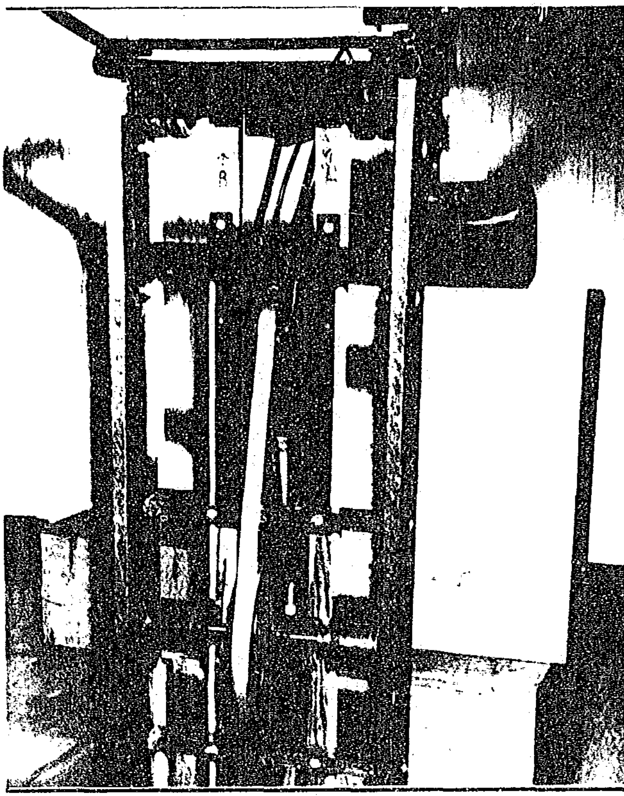

Figure 6. The underside of the NordicTrack Achiever showing the flywheel, drive rollers, and drag assembly.

of the flywheel for the NCS are greater than the NTA because with each backward leg stroke, the smaller drive roller and flywheel of the NCS will turn more often to cover the same distance as the larger drive roller and flywheel of the NTA. Even with the circumference and ratio difference, the measured resistance on the legs seemed to be accurately indicated by each resistance indicator (see Appendix D).

adjustment (see Appendix D). This was done to facilitate accurate and consistent reading of the leg resistance scale on the NCS. The leg resistance indicator seems to accurately reflect the applied resistance from the friction strap similar to a spring scale (see Appendix D). Figure 8 shows the NTA leg resistance indicator having an indicator needle with the resistance scale. This leg resistance indicator also seems to accurately indicate the applied resistance from the friction strap (see Appendix D) and is very similar to a spring scale. Note that the leg

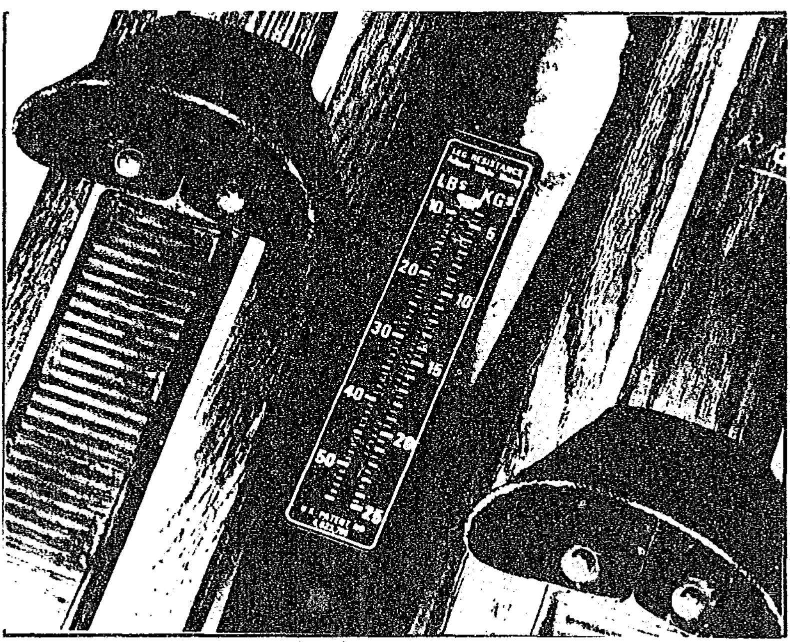

Figure 8. The leg resistance indicator of the NordicTrack Achiever with its own indicator needle, and the resistance scale with pounds and kilograms.

resistance indicator has two different resistance scales; one in pounds and one in kilograms. Since the leg resistance indicator of the NCS indicates resistance only in pounds, the unit selected for resistive measurement was the pound.

The arm exerciser on each machine is identical except for the disc brake pads of the friction system, and the resistance scales. Figures 9 and 10 show the NTA and the NCS arm exercise ergometers, respectively, with tension knobs, indicator needles and resistance scales. The

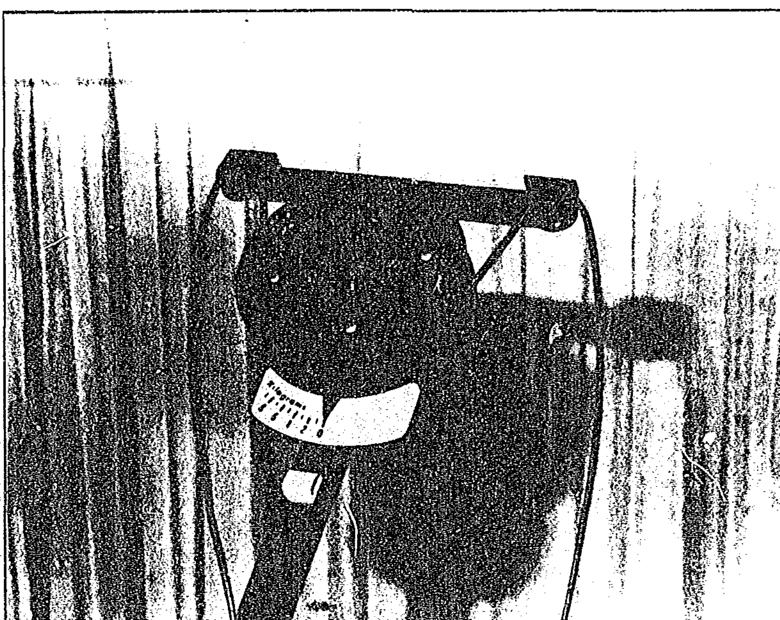

Figure 9. The arm ergometer of the NordicTrack Achiever showing the tension knob, indicator needle, and resistance scale.

resistance or tension is created by friction from compression of the brake pad. The indicator needle indicates the amount of applied resistance as the tension knob is adjusted. Since the resistance indicator for the arm ergometer of the NTA only has kilograms as the unit of measure for resistance, the selected unit for resistive measurement was the kilogram. The NTA utilizes a felt pad for the disc braking system, and the NCS uses a leather brake pad. Except for annual oiling of the bearings, the

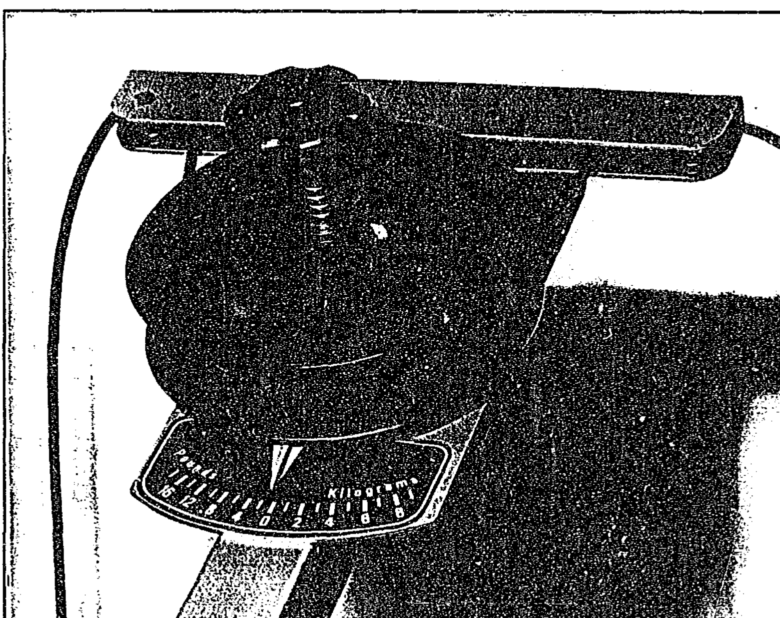

Figure 10. The arm ergometer of the NordiCare Strider showing the tension knob, indicator needle, and resistance scale in pounds and kilograms.

NTA arm exerciser is said to be maintenance free (NordicTrack, 1983). Besides annual oiling of the bearings, the NCS arm exerciser requires monthly oiling of the leather brake pad which otherwise tends to dry out and interfere with its smooth operation (NordiCare Strider, 1991).

NordicTrack Research

Despite having been on the market since 1976 (NordicTrack Inc., 1989, 1991), few extensive studies have been completed on the NordicTrack. The primary reason may be due to the difficulty of comparing work rates on the NordicTrack to other forms of exercise. According to Goss et al. (1989), the power output of the NordicTrack was variable and less precise than other ergometers because the arm and leg resistance settings could not be calibrated.

The lack of effort or ability to calibrate may be superseded by other means of standardizing work between two exercise devices. A study by Cunningham and Cantu (1990) laid credence to previous studies of the NordicTrack where HR was used as an indicator for workload when comparing metabolic responses to an exercise. They found that the relationship of HR to oxygen consumption was constant between exercise devices finding no difference in HR at 50, 60, & 70% of VO_2peak, and concluded that exercise intensity is generalizable to all modes of exercise.

Despite the complexity of controlling, measuring, and comparing the mechanical work when using the NordicTrack ski machines, energy cost, training, and comparison studies have been done.

Energy Cost Studies

The primary purpose for development of the NordicTrack was to bring the known cardiovascular benefits of cross-country skiing to the cross-country skier and to the general public, while eliminating battling unfavorable climatic conditions (NordicTrack Inc., 1989).

The aerobic demand on the body when exercising using a NordicTrack ski machine was supported by a study by Goss et al. (1989). Five healthy, active college age males completed four exercise sessions on the NordicTrack, with three randomly assigned trials within each session. The arm and leg resistances, and movement frequencies were adjusted for each 6 minute trial. They found that there was a significant increase in oxygen consumption as movement frequency increased regardless of the arm and leg resistance.

With regard to energy expenditure while using the NordicTrack, a few studies have been done. An unpublished study by Tesch (1988), developed an equation for the energy cost of exercise on the NordicTrack. Six college-age subjects (4 males, and 2 females), participated in four testing sessions with three levels of work within a test. The 4 minute workloads were designed so that either the arm load, leg load, speed, or elevation was varied while holding the other three constant. This was done to more specifically identify the oxygen consumption when one of the parameters was varied. It was found that a 50% greater increase in oxygen consumption occurred when arm load was increased 1 kilogram compared to a 1 kilogram increase in leg load.

Another study developed weight-adjusted prediction equations of energy expenditure for the NordicTrack. Bowes (1989) utilized 20 trained male cross-country skiers, 15-43 years of age, who were randomly assigned to 30 different exercise stages varying in speed, and arm and/or leg resistance. The stages were equally split into two test days and each stage was 3 minutes in duration. A metronome was adjusted to suit the subjects stride length and keep the speed constant. Oxygen consumption, HR, R, RR, VCO_2, and V_E were the measured physiologic and metabolic parameters. Caloric prediction equations and caloric estimate charts were developed for arm, leg, and combined arm and leg exercise from the subject's mass, arm pull rate, speed, and arm and/or leg resistance. A constant conversion value of 4.9 Kcals per liter of oxygen consumed was used since the average R was .88. The results of the prediction equations demonstrated that body weight had a significant effect on energy expenditure when using the NordicTrack. The predicted energy expenditure was similar to the actual expenditure, based on cross-validation with 10 different subjects.

According to the American College of Sports Medicine (ACSM) (1991), the involvement of a large muscle mass when exercising requires greater oxygen consumption then when exercising a smaller muscle mass. Therefore, functional exercise tests generally employ an exercise mode which incorporates the legs (ACSM, 1991). Recently, the theory that greater muscle involvement will elicit greater oxygen consumption was tested by using the NordicTrack. Hinze (1990) compared maximal treadmill running to maximal simulated skiing using the NTA. His study involved 14 males, 21-34 years of age, who went through three practice sessions on the NTA, and were then assigned to randomized maximal testing by each mode. Significant differences were found in maximal VO_2 and HR with the NTA being lower in both cases. No significant differences in maximal V_E and RER were observed.

In another study, the effects of increased muscle mass on maximal oxygen consumption using simulated cross-country skiing were studied. Bart, Dorsen, and Leon (1990) studied 6 men and 5 women, 18-21 years of age, who were members of a university cross-county ski team. The testing sessions for both the treadmill and the NordicTrack were 3 minute discontinuous stages until maximal effort was achieved. For the NordicTrack protocol, the speed, leg resistance, and elevation changed while the arm resistance was constant at 1 kilogram. The treadmill test was performed using the modified Bruce protocol. The results indicated no significant difference between the treadmill and the NordicTrack in maximal values of VO_2, HR, V_E, and RPE. It was hypothesized that the nonsignificant differences may have been due to the subjects being competitive cross-country skiers.

Training Studies

Training studies to determine enhancement of the cardiovascular system and body composition while using the NordicTrack ski simulator have concluded that benefits exist. In a study by Thetford (1984), 32 college-age males, 18 to 22 years of age, were involved in a 12-week training study to determine the effectiveness of two different modes of training on maximal oxygen consumption and body composition. The subjects were randomly assigned to jogging or NordicTrack so that 12 were in each group. Eight subjects constituted the nonaerobic activity control group. As measured by underwater weighing, a significant improvement in body composition resulted with both jogging and using the NordicTrack as compared to the control group, but no difference existed between the two modes. There was also a small improvement in maximal oxygen consumption in both exercise groups, but it was not statistically significant. This nonsignificance was attributed to the high initial level of fitness, or the short length and low intensity of the training program. The author concluded that similar training benefits exist when frequency, duration, and intensity are similar, regardless of the mode of aerobic activity chosen.

Another training study by Jacobsen, Leon, Wang, Serfass, and Hunninghake (1986) looked exclusively at the effects of 19 weeks of simulated cross-country skiing on maximal oxygen consumption, body fat, and blood lipid levels. Twelve sedentary females aged 20 to 40 years were compared to 10 females in a control group. The intensity was the typical 50-80% of heart rate reserve with duration progressing from 20 to 40 minutes, 4 times per week. As measured by underwater weighing, the percent body fat and body weight decreased, but not significantly. A 12% increase in VO_2max was evident as determined by a Bruce treadmill protocol. Total cholesterol, HDL, and triglycerides did not change.

Comparison Studies

Knowing that beneficial metabolic and physiologic responses occur when exercising on the NordicTrack, the next logical step was to compare these results to other modes of exercise. Four known studies have been done addressing such comparisons. The first known comparison study by Thetford (1984) involving the NordicTrack in a training study was previously discussed at length. Generally, Thetford concluded that an exercise program using the NordicTrack resulted in a reduction in percent body fat, and an increase in maximal oxygen consumption similar to what would be seen with a jogging program.

Two other comparison studies were done on the NordicTrack by Allen and Goldberg (1986a, 1986b). One study was a direct comparison of the NordicTrack to another cross-country ski simulator, and the other study was a comparison of the NordicTrack to a rowing machine and a bicycle ergometer. The ski machine comparison by Allen and Goldberg (1986b) involved eight active males who completed a continuous, incremental maximal test with 2 minute stages on each machine. Four practice sessions on each ski simulator were required, and the order of testing was randomized. The results found significantly greater maximal VO_2, and greater oxygen consumption at three submaximal heart rates when using the NordicTrack. Because maximal values in HR, V_E, RER, and total time were not significantly different while maximal oxygen consumption was different, the authors concluded that exercise on the NordicTrack would give a greater cardiorespiratory workout than when exercising on the other ski simulator.

In the other NordicTrack comparison study by Allen and Goldberg (1986a), eight active males exercised to exhaustion on a rowing machine, a bicycle ergometer, and a NordicTrack. The order of the maximal tests was randomized and separated by at least 24 hours. The results indicated no significant differences between devices in maximal HR, but a significantly greater maximal oxygen consumption was achieved when using the NordicTrack. Also, at two selected submaximal heart rates the oxygen consumption was significantly higher for the NordicTrack. Thus, the authors concluded that exercise with the NordicTrack gave a greater cardiorespiratory workout.

In the most recent study comparing submaximal metabolic responses of the NordicTrack to other exercise modes, a prolonged, constant intensity design was used. Thomas, Feiock, and Araujo (1989) had five healthy, active males, ages 19 to 29 years, exercise at a constant intensity of 65% of maximal HR for 60 minutes on each of four exercise modes. The maximal heart rates for each subject were determined from a maximal cycle test on a Monarck bicycle ergometer. Three practice sessions for habituation were used on the rower and the NordicTrack, and two for the treadmill and bicycle. The order of testing was randomly assigned, with testing following the practice sessions for each mode. The absolute oxygen consumption among exercise modes was not significantly different during the constant intensity as measured at 65% of maximal HR, nor was the RER, total energy, and fat energy. It was noted that the rate of fat expenditure for all modes was significantly higher after 20 minutes of exercise which corresponded to the nonsignificant decline in RER. Also, at the selected intensity level, exercise on the NordicTrack and the treadmill resulted in a larger percentage of the total energy expenditure coming from fat. The authors concluded that cardiovascular and metabolic responses to exercise at comparable relative heart rates were similar among the NordicTrack, cycle ergometer, rower, and treadmill (walking).

Summary

This review of related literature addressed the major mechanical differences in the NordicTrack ski simulator models, and presented the studies involving the NordicTrack ski simulator. The development of new exercise models such as the NCS, marketed for rehabilitative and commercial fitness settings, gives exercising individuals a choice in an aerobic training device. Since the NordicTrack ski simulators are becoming more available, it is important to establish reliable information about physiologic and metabolic responses to exercise on all the NordicTrack models. The lack of literature found regarding the NCS necessitates the need for further research of this ski simulator. Therefore, this study will compare the metabolic and physiologic responses to exercise when using the NTA and the NCS.

CHAPTER III

METHODS AND PROCEDURES

Introduction

This study compared the metabolic and physiologic responses of exercise on the NordicTrack Achiever and the NordiCare Strider at equivalent work settings. The research methods employed addressed the following areas: subject selection, instrumentation, pilot testing, testing procedures, and statistical analyses.

Subject Selection

Male volunteers, ages 18 to 40 years, were recruited from the University of Wisconsin-La Crosse (UW-L) and the surrounding community during the summer of 1992. The subjects needed to meet criterion before selection based on completion of the Health History/Activity Profile Form (see Appendix A). The selected subjects met the following criteria: 1) were apparently healthy with no cardiovascular, metabolic, or orthopedic problems, 2) were on no medications which affected HR or blood pressure during exercise, 3) were nonsmokers, and 4) were actively participating in vigorous aerobic activity (i.e., exercise HR > 60% of maximal, exercise intensity > 60% of VO_2max, or RPE > 12) at least three times per week. After selection of subjects who met the minimum requirements for participation, a mutually agreed upon testing time for each subject was established. An informed consent form (see Appendix B) was then administered and explained to the subjects at the first scheduled test. Each subject was required to complete the form prior to any testing.

Instrumentation

The equipment used for physiological measurements in this study was the equipment available at the UW-L Human Performance Laboratory. The Quinton Q-Plex metabolic cart (Quinton Instruments Company, 1989) was used for the measurement of metabolic responses. Calibration of the gas analyzers was performed before each testing session with known oxygen and carbon dioxide gas concentrations determined by the method of Scholander (1947). A Polar HR monitor and watch (Polar USA, Inc., 1989) were used to measure HR, and the NTA and NCS ski machines (NordicTrack, Inc., 1991; NordiCare, 1991) were the devices being compared.

Pilot Testing

A pilot test was conducted prior to the main experimental study. The pilot study involved three volunteers and was conducted to establish a testing protocol over a wide range of arm and leg resistances. It was found that differences in metabolic response between the NTA and the NCS did exist; therefore, the study design of a separate arm test and a leg test was developed to identify where the differences existed.

Testing Procedures

Before the experimental testing, each subject was required to complete three practice sessions. Subjects were then given both an arm and a leg test, on each of two separate days.

Practice Session

The subjects reported to the Human Performance Laboratory at UW-L for the practice sessions. Upon arrival, the subjects were given an informed consent form to read and sign. Explanations of the consent form, the testing protocol, and the risks involved accompanied its administration. Signature of the form stating an understanding of the procedures and agreement to participate in the learning and testing sessions was required before the subject was allowed to participate.

To ensure a basic skill level in the use of the NTA and the NCS, each subject was required to attend three practice sessions. Each of the two NordicTrack ski machines was used for 10 minutes during each practice session, so that the subject became equally familiar with both. These sessions also were used to familiarize the subject with the testing equipment which included the headgear, nose clip, and mouth piece, and to familiarize the subject with the testing protocol.

Testing Session

The subjects participated in two randomized (see Appendix C) testing sessions on separate days with arm and leg tests conducted during each session. Each subject reported to the Human Performance Laboratory rested and having abstained from food, tobacco, alcohol, and caffeine for at least 3 hours before the testing session. The subject was weighed to the nearest 0.5 pound using a single beam scale (Continental model #200 DLK, Health-O-Meter). The weight included the clothes worn during testing. Then, the height of the subject with shoes was measured to the nearest 0.5 inch by a stadiometer scale attached to the wall.

Next, the subject was fitted with the headgear, nose clip, and nonrebreathing valve which directed the expired air to the Q-Plex. A HR transmitter strap was adjusted to fit snugly around the chest, and a receiver watch, attached to the ski machine, was used to measure HR. The Q-Plex was calibrated with known gas concentrations as determined by the Scholander (1947) method and programmed for averages of gas analysis at 60 second intervals. The leg and arm ergometer resistance indicators were checked after each testing day to document actual resistance (see Appendix D). Also, the resistance indicators were constantly monitored, and the tension was adjusted if necessary to maintain a consistent setting during the test stages.

As predetermined by randomization, the subject performed either the NTA arm or leg test first, or the NCS arm or leg test first. The opposite muscle group of the muscle group that was tested first was tested second.

The subject began with an initial warm-up stage, and it was the same for both the leg and arm tests. The work setting of the initial stage was set at 9 pounds of resistance on the legs and zero kilograms on the arms. As previously mentioned, the resistances and protocol were developed from the pilot testing. Since there were no pound units on the NTA arm ergometer, the unit of kilograms was selected for the measurement of arm resistance on the NTA and the NCS. It was noted through pilot testing, that during combined arm and leg work, an arm to leg resistance ratio of 1:4 elicited a comfortable combination. The arm resistances were selected based on: 1) the range of work the resistances would elicit, and 2) the ability to consistently and accurately read the resistance indicator. The leg resistances were four times the arm resistances and converted to the nearest pound.

Then, according to the predetermined randomized testing sequence, the subject followed either the arm or leg protocol.

<u>The arm protocol</u>. Following the baseline warm-up stage, the subsequent 4 minute stages and work settings for the arm test on either the NTA or the NCS followed the

protocol of 1.0, 1.5, 2.0, and 2.5 kg, while the legs maintained a constant work setting of 9 pounds throughout the test. If the arm test was done first, there was a rest period of 10 minutes before testing the legs. During this time the subject was allowed to remove the headgear and mouthpiece, walk, stretch, and drink water.

The leg protocol. Following the baseline warm-up stage, the subsequent 4 minute stages and work settings for the leg test on either the NTA or the NCS followed the protocol of 13, 18, and 22 lbs, while the arms maintained a constant work setting of 0 kilograms. If the leg test was done first, there was a rest period of 10 minutes before testing the arms. During this time the subject was allowed to remove the headgear and mouthpiece, walk, stretch, and drink water.

Heart rate was measured at the end of every minute and recorded. The rating of perceived exertion (RPE) was recorded at the end of each 4 minute steady-state stage. The RPE using the Borg 6-20 scale (Borg, 1973) was explained at the beginning of the testing session. Since the subject was unable to point or verbalize the effort due to the nature of the exercise and the testing measurements, the primary investigator chronologically pointed to each number on the scale until the subject indicated the appropriate exertion level by a positive head nod. The metabolic measurements analyzed by the Q-plex were recorded every 60 seconds.

Statistical Analyses

The demographic information on the subjects was summarized using standard descriptive statistics. Paired t-tests were performed to determine differences between the NTA arm ergometer and NCS arm ergometer, and differences between the NTA leg ergometer and NCS leg ergometer for all variables. Alpha level was set at $p < .05$ for all analyses.

CHAPTER IV

RESULTS AND DISCUSSION

Introduction

This study compared the metabolic and physiologic responses of exercising on the NTA and the NCS at equivalent work settings. This chapter presents the results of the study and discusses the findings of comparing the NordicTrack Achiever arms (NTarms) to the NordiCare Strider arms (NSarms), and the NordicTrack Achiever legs (NTlegs) to the NordiCare Strider legs (NSlegs) for all analyzed variables. The findings are addressed in the following order: subject characteristics, results of comparing NTarms to NSarms, and NTlegs to NSlegs for all variables, and discussion of results.

Subject Characteristics

Twenty-four subjects participated in the study. Through practice sessions, all subjects were assumed to have acquired a minimum level of efficiency in the use of both the NTA and the NCS. All subjects completed two required testing sessions. The testing sessions were randomized to minimize any influential effects of order on the findings. This was accomplished by equally matching the subjects to the eight random combinations (see Appendix C). The descriptive characteristics for the 24 subjects are presented in Table 1.

Table 1. Descriptive characteristics of subjects

Variable	Mean	Standard Deviation	Range
Age (years)	26.5	5.97	20 to 40
Height (in)	70.5	2.59	66 to 75
Weight (lbs)	173.0	20.3	132 to 210

<u>Results of the Comparisons</u>

Differences between the NTA arm ergometer and the NCS arm ergometer, and differences between the NTA leg ergometer and the NCS leg ergometer were determined using paired t-tests. The differences were determined for each of the five stages for the arms, and each of the four stages for the legs for all measured variables. The following tables for each measured variable were developed.

In Tables 2 and 3, a comparison of oxygen consumption (VO_2) was made between the NCS arm ergometer and the NTA arm ergometer. Significantly ($p < .05$) greater oxygen consumption was required, when exercising the arms for each of five stages, on the NCS, compared to the NTA.

In Tables 4 and 5, a metabolic comparison of relative and absolute oxygen consumption (VO_2) was made between the use of the NCS leg ergometer and the NTA leg ergometer. No significant ($p > .05$) differences in oxygen consumption

Table 2. Comparison of VO_2 (ml/kg/min) for arms

Stage	Resistance Arms (kg)	Legs (lb)	NSarms ($\bar{x} \pm SD$)	NTarms ($\bar{x} \pm SD$)	Difference
1	0.0	9	27.6 ± 5.39	26.0 ± 4.88	1.6*
2	1.0	9	31.4 ± 6.06	29.2 ± 5.31	2.2*
3	1.5	9	33.9 ± 6.04	30.9 ± 5.64	3.0*
4	2.0	9	35.7 ± 6.47	32.4 ± 5.80	3.3*
5	2.5	9	37.5 ± 6.89	34.1 ± 6.25	3.4*

Note. NordicTrack Achiever arms = NTarms.
NordiCare Strider arms = NSarms.
* = Significant difference between NSarms and NTarms ($p < .05$)

Table 3. Comparison of VO_2 (L/min) for arms

Stage	Resistance Arms (kg)	Legs (lb)	NSarms ($\bar{x} \pm SD$)	NTarms ($\bar{x} \pm SD$)	Difference
1	0.0	9	2.15 ± 0.366	2.02 ± 0.341	0.13*
2	1.0	9	2.44 ± 0.413	2.27 ± 0.354	0.17*
3	1.5	9	2.63 ± 0.418	2.39 ± 0.373	0.24*
4	2.0	9	2.77 ± 0.424	2.51 ± 0.395	0.26*
5	2.5	9	2.91 ± 0.467	2.65 ± 0.431	0.26*

Note. NordicTrack Achiever arms = NTarms.
NordiCare Strider arms = NSarms.
* = Significant difference between NSarms and NTarms ($p < .05$)

existed at stages 1, 3, and 4 between devices. Stage 2 produced a significant difference ($p < .05$), with leg exercise on the NCS resulting in a higher oxygen consumption compared to the NTA.

Table 4. Comparison of VO_2 (ml/kg/min) for legs

Stage	Resistance Arms (kg)	Resistance Legs (lb)	NSlegs ($\bar{x} \pm SD$)	NTlegs ($\bar{x} \pm SD$)	Difference
1	0.0	9	26.8 ± 4.80	26.1 ± 4.72	0.7
2	0.0	13	30.2 ± 5.76	28.7 ± 5.17	1.5*
3	0.0	18	32.5 ± 6.37	32.2 ± 6.22	0.3
4	0.0	22	34.6 ± 7.32	34.7 ± 7.03	-0.1

Note. NordicTrack Achiever legs = NTlegs.
NordiCare Strider legs = NSlegs.
* = Significant difference between NSlegs and NTlegs ($p < .05$)

Table 5. Comparison of VO_2 (L/min) for legs

Stage	Resistance Arms (kg)	Resistance Legs (lb)	NSlegs ($\bar{x} \pm SD$)	NTlegs ($\bar{x} \pm SD$)	Difference
1	0.0	9	2.09 ± 0.337	2.03 ± 0.325	0.06
2	0.0	13	2.34 ± 0.379	2.22 ± 0.357	0.12*
3	0.0	18	2.52 ± 0.429	2.49 ± 0.419	0.03
4	0.0	22	2.68 ± 0.502	2.69 ± 0.475	-0.01

Note. NordicTrack Achiever legs = NTlegs.
NordiCare Strider legs = NSlegs.
* = Significant difference between NSlegs and NTlegs ($p < .05$)

Tables 6 and 7 present data for minute ventilation (V_E) for the arms and legs. Ventilation was significantly ($p < .05$) greater at all stages during arm exercise on the NCS, and at stage 2 during leg exercise. There were no significant ($p > .05$) differences in ventilation during leg exercise between the NTA and the NCS at stages 1, 3, and 4.

Table 6. Comparison of V_E (liters) for arms

Stage	Resistance Arms (kg)	Legs (lb)	NSarms ($x \pm$ SD)	NTarms ($x \pm$ SD)	Difference
1	0.0	9	52.3 ± 8.74	48.0 ± 8.36	4.3*
2	1.0	9	62.2 ± 11.68	55.7 ± 8.72	6.5*
3	1.5	9	70.0 ± 13.05	59.9 ± 9.16	10.1*
4	2.0	9	76.5 ± 14.58	64.2 ± 10.93	12.3*
5	2.5	9	83.1 ± 19.08	68.9 ± 12.55	14.2*

<u>Note</u>. NordicTrack Achiever arms = NTarms.
NordiCare Strider arms = NSarms.
* = Significant difference between NSarms and NTarms ($p < .05$)

Arm exercise with the NCS produced a significantly ($p < .05$) higher RER at stages 2, 3, 4, and 5 compared to the NTA (see Table 8). No significant differences ($p > .05$) were found for each of the four stages during leg exercise (see Table 9), and during arm exercise for stage 1.

Heart rate was significantly ($p < .05$) higher during arm exercise with the NCS at stages 2, 3, 4, and 5 compared

Table 7. Comparison of V_E (liters) for legs

Stage	Resistance Arms (kg)	Legs (lb)	NSlegs ($x \pm SD$)	NTlegs ($x \pm SD$)	Difference
1	0.0	9	51.0 ± 8.88	47.8 ± 7.35	3.2
2	0.0	13	59.1 ± 12.13	54.4 ± 8.42	4.7*
3	0.0	18	65.2 ± 14.63	62.9 ± 12.36	2.3
4	0.0	22	70.2 ± 19.61	71.0 ± 15.90	-0.8

Note. NordicTrack Achiever legs = NTlegs.
NordiCare Strider legs = NSlegs.
* = Significant difference between NSlegs and NTlegs ($p < .05$)

Table 8. Comparison of RER for arms

Stage	Resistance Arms (kg)	Legs (lb)	NSarms ($x \pm SD$)	NTarms ($x \pm SD$)	Difference
1	0.0	9	0.87 ± 0.027	0.86 ± 0.037	0.01
2	1.0	9	0.92 ± 0.028	0.90 ± 0.035	0.02*
3	1.5	9	0.94 ± 0.032	0.92 ± 0.031	0.02*
4	2.0	9	0.95 ± 0.042	0.92 ± 0.033	0.03*
5	2.5	9	0.95 ± 0.041	0.93 ± 0.036	0.02*

Note. NordicTrack Achiever arms = NTarms.
NordiCare Strider arms = NSarms.
* = Significant difference between NSarms and NTarms ($p < .05$)

to arm exercise with the NTA, but no significant ($p > .05$) difference existed at stage 1 (see Table 10). Heart rates for all stages during leg exercise, were not significantly (p > .05) different between machines (see Table 11).

Table 9. Comparison of RER for legs

Stage	Resistance Arms (kg)	Resistance Legs (lb)	NSlegs (x ± SD)	NTlegs (x ± SD)	Difference
1	0.0	9	0.86 ± 0.049	0.84 ± 0.041	0.02
2	0.0	13	0.91 ± 0.038	0.89 ± 0.035	0.02
3	0.0	18	0.92 ± 0.041	0.92 ± 0.043	0.00
4	0.0	22	0.93 ± 0.047	0.93 ± 0.042	0.00

Note. NordicTrack Achiever legs = NTlegs.
NordiCare Strider legs = NSlegs.
* = Significant difference between NSlegs and NTlegs ($p < .05$)

Table 10. Comparison of heart rate (bpm) for arms

Stage	Resistance Arms (kg)	Resistance Legs (lb)	NSarms (x ± SD)	NTarms (x ± SD)	Difference
1	0.0	9	129 ± 15.8	126 ± 13.1	3
2	1.0	9	142 ± 17.6	136 ± 13.3	6*
3	1.5	9	151 ± 17.8	143 ± 15.0	8*
4	2.0	9	157 ± 18.8	148 ± 15.3	9*
5	2.5	9	162 ± 19.0	153 ± 16.2	9*

Note. NordicTrack Achiever arms = NTarms.
NordiCare Strider arms = NSarms.
* = Significant difference between NSarms and NTarms ($p < .05$)

Table 11. Comparison of heart rate (bpm) for legs

Stage	Resistance Arms (kg)	Resistance Legs (lb)	NSlegs ($x \pm SD$)	NTlegs ($x \pm SD$)	Difference
1	0.0	9	127 ± 15.6	127 ± 12.3	0
2	0.0	13	137 ± 17.0	136 ± 15.1	1
3	0.0	18	144 ± 18.9	146 ± 16.6	-2
4	0.0	22	149 ± 20.1	153 ± 18.5	-4

Note. NordicTrack Achiever legs = NTlegs.
NordiCare Strider legs = NSlegs.
* = Significant difference between NSlegs and NTlegs ($p < .05$)

Table 12 indicates that RPE was significantly ($p < .05$) greater during arm exercise on the NCS for stages 2, 3, 4,

Table 12. Comparison of RPE for arms

Stage	Resistance Arms (kg)	Resistance Legs (lb)	NSarms ($x \pm SD$)	NTarms ($x \pm SD$)	Difference
1	0.0	9	8.4 ± 1.38	8.0 ± 2.01	0.4
2	1.0	9	10.5 ± 1.79	9.8 ± 2.08	0.7*
3	1.5	9	12.1 ± 2.02	11.3 ± 2.16	0.8*
4	2.0	9	13.6 ± 2.55	12.5 ± 2.32	1.1*
5	2.5	9	14.9 ± 2.97	13.4 ± 2.52	1.5*

Note. NordicTrack Achiever arms = NTarms.
NordiCare Strider arms = NSarms.
* = Significant difference between NSarms and NTarms ($p < .05$)

and 5, but not significantly ($p > .05$) different for stage 1. There were no significant ($p > .05$) differences in RPE for any of the leg stages (see Table 13).

Table 13. Comparison of RPE for legs

Stage	Resistance Arms (kg)	Resistance Legs (lb)	NSlegs ($\bar{x} \pm SD$)	NTlegs ($\bar{x} \pm SD$)	Difference
1	0.0	9	8.3 ± 1.63	8.2 ± 1.25	0.1
2	0.0	13	10.3 ± 1.99	10.3 ± 1.68	0.0
3	0.0	18	11.8 ± 2.12	12.0 ± 2.14	-0.2
4	0.0	22	13.2 ± 2.53	13.5 ± 2.65	-0.3

Note. NordicTrack Achiever legs = NTlegs.
NordiCare Strider legs = NSlegs.
* = Significant difference between NSlegs and NTlegs ($p < .05$)

Tables 14 and 15 show the average revolutions per minute of the flywheel for each stage, as counted by a magnetic counter, during the arm test and the leg test respectively. Significant ($p > .05$) differences in flywheel revolutions, for all stages of arm and leg exercise, were the result of the flywheel circumferences being different. It was interesting to note that the revolutions for successive stages of the arm test increased as the arm resistance increased, even though a fixed cadence was maintained by the arms and legs. Conversely, the revolutions for successive stages of the leg test decreased as the leg resistance increased, even though a constant cadence was maintained by the arms and legs. Because the

Table 14. Comparison of flywheel revolutions (rpm) generated by the legs during the arm test

Stage	Resistance Arms (kg)	Resistance Legs (lb)	NSarms ($x \pm SD$)	NTarms ($x \pm SD$)	Difference
1	0.0	9	545 ± 132.4	351 ± 75.5	194*
2	1.0	9	577 ± 127.8	371 ± 70.8	206*
3	1.5	9	604 ± 129.0	382 ± 71.8	222*
4	2.0	9	614 ± 122.6	389 ± 73.1	225*
5	2.5	9	630 ± 133.0	396 ± 77.9	234*

Note. NordicTrack Achiever arms = NTarms.
NordiCare Strider arms = NSarms.
* = Significant difference between NSarms and NTarms ($p < .05$)

Table 15. Comparison of flywheel revolutions (rpm) generated by the legs during the leg test

Stage	Resistance Arms (kg)	Resistance Legs (lb)	NSlegs ($x \pm SD$)	NTlegs ($x \pm SD$)	Difference
1	0.0	9	520 ± 134.4	337 ± 79.6	183*
2	0.0	13	514 ± 117.4	334 ± 79.2	180*
3	0.0	18	505 ± 122.4	328 ± 76.4	177*
4	0.0	22	496 ± 123.5	322 ± 71.0	174*

Note. NordicTrack Achiever legs = NTlegs.
NordiCare Strider legs = NSlegs.
* = Significant difference between NSlegs and NTlegs ($p < .05$)

stride length of the legs was not measured, it was not possible to determine if stride length changed across trials.

The work done on the flywheel was assumed constant during each stage for both the NTA and the NCS based on the assumed validity of the fixed resistance settings and a consistently maintained cadence. In an attempt to further support this assumption, a theoretical calculation of work done on the flywheel was made for both the NTA and the NCS. The work done on the flywheel generated by the legs during the arm and leg tests was calculated as described in Appendix E. The work done by the arms was not calculated because neither an accurate measure of arm stroke length, nor a measure of the number of revolutions of the arm resistance spool was developed. Therefore, work done by the arms on the NTA and the NCS could only be assumed constant.

No significant ($p > .05$) differences in work done on the flywheel existed at any stage between the NTA and the NCS, as indicated in Table 16 during the arm test, and Table 17 during the leg test.

During the arm test no differences were expected in the work done on the flywheel by the legs because the legs were at an assumed constant resistance and cadence while the work done by the arms was increasing. The work done by the legs on the flywheel was the same for both the NTA and the NCS at equivalent work settings. This supported the assumption

Table 16. Comparison of work done on the flywheel (kpm/min) generated by the legs during the arm test

Stage	Resistance Arms (kg)	Resistance Legs (lb)	NSarms ($\bar{x} \pm$ SD)	NTarms ($\bar{x} \pm$ SD)	Difference
1	0.0	9	274 $\pm$ 66.5	275 $\pm$ 59.2	-1
2	1.0	9	290 $\pm$ 64.2	291 $\pm$ 55.5	-1
3	1.5	9	304 $\pm$ 64.9	300 $\pm$ 56.3	4
4	2.0	9	308 $\pm$ 61.6	305 $\pm$ 57.3	3
5	2.5	9	317 $\pm$ 66.8	311 $\pm$ 61.1	6

Note. NordicTrack Achiever arms = NTarms.
NordiCare Strider arms = NSarms.
* = Significant difference between NSarms and NTarms ($p < .05$)

Table 17. Comparison of work done on the flywheel (kpm/min) generated by the legs during the leg test

Stage	Resistance Arms (kg)	Resistance Legs (lb)	NSlegs ($\bar{x} \pm$ SD)	NTlegs ($\bar{x} \pm$ SD)	Difference
1	0.0	9	261 $\pm$ 67.5	264 $\pm$ 62.4	-3
2	0.0	13	373 $\pm$ 85.2	379 $\pm$ 89.8	-6
3	0.0	18	508 $\pm$ 123.0	515 $\pm$ 119.8	-7
4	0.0	22	610 $\pm$ 151.7	617 $\pm$ 136.1	-7

Note. NordicTrack Achiever legs = NTlegs.
NordiCare Strider legs = NSlegs.
* = Significant difference between NSlegs and NTlegs ($p < .05$)

that the leg resistance settings and cadence were consistent between the NTA and NCS. However, it is not readily apparent why the work done on the flywheel by the legs increased as the arm resistance increased on both the NTA and the NCS.

<u>Discussion of the Results</u>

This study was developed to determine if differences existed in the metabolic and physiologic responses to exercise between the NTA and the NCS at equivalent resistance settings. Using paired t-tests for each variable at each stage, a comparison between the NTA arm ergometer to the NCS arm ergometer, and the NTA leg ergometer to the NCS leg ergometer was possible.

The results indicated significant differences for all stages between the NTA and the NCS during arm exercise, both in absolute (L/min) and relative (ml/kg/min) oxygen consumption, and in ventilation. Significant differences between the two exercise devices during arm exercise were present for all stages except stage 1, for RER, HR, and RPE. Conversely, no significant differences between the NTA and the NCS during leg exercise were indicated for RER, HR, and RPE at any stage. An isolated significance during leg exercise was noted in stage 2 for both absolute (L/min) and relative (ml/kg/min) oxygen consumption, and ventilation. No explanation for this is immediately obvious.

For this study, it was assumed that the work done by a subject on each NordicTrack ski simulator at each stage was constant. This assumption was based on the assumed validity of both the arm and leg resistance indicators, and the assumed reliability of the subject to maintain a set cadence of 60 cycles/minute. If differences were found in metabolic and physiologic responses between the NTA and the NCS at equivalent work settings, it would lead to the conclusion that the mechanical work was not equal. Therefore, if differences existed, either the assumption was incorrect with regard to cadence reliability and/or resistance validity, or there was work done that was not measured by the resistance indicator. Thus, work may have been done that was unaccounted for by the resistance indicator yet was metabolically and physiologically measurable, which is inherent in the mechanical design and functioning of the device. The possibility that work was being done which was not measured by the resistance indicator was anticipated because the forward leg resistance of the NCS was found to be higher than the NTA. The NCS was measured at 2.5 lbs of forward leg resistance, and the NTA was measured at .0 lbs (see Appendix D).

The results indicated significant differences for all stages between the NTA and the NCS during arm exercise both in absolute (L/min) and relative (ml/kg/min) oxygen consumption, and in ventilation. This finding led to the conclusion of the null hypotheses which stated no difference would exist in exercising VO_2 expressed in absolute (L/min) or relative (ml/kg/min) terms, and no difference would exist in exercise ventilation response. Significant differences during arm exercise were present for all stages except stage 1, for RER, HR, and RPE. While the complete rejection of the null hypotheses for these variables would not be appropriate, a rejection of the hypotheses for the stages where significance existed, and acceptance of the hypotheses for the one isolated nonsignificance may be allowable. These findings can possibly be explained by the arm workloads being different because the arm resistance indicators were not accurate. It was observed, through the posttest measurements of the arm ergometer, that the resistance indicator of the NTA arm ergometer was consistent at all stages with the actual resistance measured by a spring scale (see Appendix D). Conversely, the resistance measured on the arm ergometer of the NCS was consistently higher than the value indicated on the spring scale at all stages (see Appendix D). Consequently, the measurably higher resistance at the resistance settings selected for the arm test protocol on the NCS resulted in greater mechanical work than on the NTA. According to ACSM (1991), the metabolic equivalent to the mechanical work done by an individual to perform a given activity is the metabolic rate of the energy expended. Therefore, since the measured resistances at equivalent arm indicator settings were higher for the NCS, and the mechanical work done was greater when arm exercising on the NCS, the metabolic and physiologic responses to the arm exercise on the NCS were greater than on the NTA.

No significant differences between the NTA and the NCS during leg exercise were indicated for RER, HR, and RPE at all stages. With this finding, the null hypotheses of no difference in RER, HR, and RPE while leg exercising were accepted. An isolated significance during leg exercise was noted in stage 2 of both absolute (L/min) and relative (ml/kg/min) oxygen consumption, and in ventilation. Therefore, the null hypotheses for stages 1, 3, and 4, which stated that when leg exercising, there would be no significant difference in either the relative (ml/kg/min) or the absolute (L/min) values of oxygen consumption, and no significant difference in the ventilation response, were accepted.

In view of the isolated significant change in oxygen consumption and ventilation in stage 2 the null hypotheses at this stage were rejected. These findings were supported by the results of the posttest measurements made on the leg ergometers with a spring scale. The leg resistance indicators, at all indicated settings of the leg ergometer, were observed to be consistent with the measured values. This observation was true for both the NTA and the NCS (see Appendix D). Therefore, since the measured resistances at the leg indicator settings used in the leg tests were accurate, the work done during the leg exercise for the NCS and the NTA at equivalent indicator settings should be equal. This was reflected by the absence of significant differences in the metabolic and physiologic responses to the leg exercise between the NCS and the NTA at most stages in the leg tests. It is difficult to explain why the constant difference in resistance between the NTA and the NCS when bringing the leg forward (see Appendix D) appeared to be metabolically and physiologically inconsequential.

The importance of these findings is determined by the practical significance they have on the intended or specific population that will be using the device. As stated earlier, the NCS is currently being marketed for cardiac rehabilitation facilities and fitness centers. Specifically, with the cardiac rehabilitation facilities, the patients medical condition would require appropriate and accurate exercise prescriptions. The current finding that nearly 1 MET more energy is required using the arm ergometer of the NCS than when using the arm ergometer of the NTA is a significant energy expenditure for cardiac patients and other individuals with limited fitness levels. Therefore, caution should be forwarded to cardiac patients and rehabilitation facilities, especially those that have both devices and use workload as an exercise prescription.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to compare the metabolic and physiological responses to exercise when using the NTA and the NCS at equivalent work settings. Twenty-four male subjects, 18 to 40 years of age and apparently healthy, were equally matched to 8 random testing combinations. Through practice sessions, the subjects developed a minimum efficiency in the use of the NTA and the NCS. All subjects completed two testing sessions.

Each testing session involved a 16 minute, four stage leg test and a 20 minute, five stage arm test with a 10 minute rest period between tests. The order of each testing session was based on random assignment. The subjects performed the leg or arm test while exercising with the opposite muscle group at the lowest measurable resistance setting. A constant 60 cycles/minute for each stage was maintained, with the work rate progressively increasing every 4 minutes through applied resistance. The variables analyzed were: absolute VO_2 (L/min), relative VO_2 (ml/kg/min), V_E (BTPS) (L/min), RER, HR (bpm), and RPE.

Descriptive statistics were used to determine the means and standard deviations for the physical characteristics of all subjects, and for the metabolic and physiologic responses at each stage of the ski simulator tests. Metabolic and physiologic differences between arm exercising on the NTA and the NCS, and between leg exercise on the NTA and the NCS were compared using paired-t tests. The level of significance was set at .05 for all analyses.

The results indicated significant differences in the response to arm exercise for both absolute (L/min) and relative (ml/kg/min) oxygen consumption, and for ventilation at all stages, between the NTA and the NCS. Responses in RER, HR, and RPE during arm exercise were also significantly different at all stages, except for stage 1. The differences were consistent with the finding that the arm resistance of the NCS was found to be higher than what was indicated by the indicator dial when checked with a spring scale. In contrast, the arm indicator dial for the NTA was consistent with the measured values.

There was no difference in the responses of RER, HR, and RPE during leg exercise between the NTA and the NCS at all stages. The responses to leg exercise in terms of both absolute (L/min) and relative (ml/kg/min) oxygen consumption, and in ventilation were not significantly different for the NCS and the NTA, except at stage 2 where an isolated significant difference existed. The lack of metabolic and physiologic differences between the NCS and the NTA during leg exercise was consistent with the spring scale measurements giving equal resistances for backward thrusting. However, the constant difference in forward resistance measured with a spring scale did not elicit different responses by the subjects.

The calculation of work done by the legs on the flywheel resulted in no significant differences between the NCS and the NTA, at all stages during the arm test and leg test. This finding supported the assumption that with a fixed cadence the work done by the legs would be constant during the arm and leg tests between the NTA and the NCS. Conversely, the work done by the arms at a fixed cadence was not equal between arm devices because at selected arm indicator settings the measured resistance was found to be higher on the NCS. The metabolic and physiological findings generally supported these mechanical work rate similarities and differences except for the difference in resistance to forward motion by the legs.

No immediate explanation can be made as to why there were significantly higher responses in relative (ml/kg/min) and absolute (L/min) oxygen consumption, and ventilation at stage 2 during leg exercise with the NCS.

The resistance of the forward leg movement is not measured by either the NCS or the NTA resistance indicator dials. The forward leg resistance of the NCS was found to be higher than the NTA. The NCS was measured at 2.5 lbs of forward leg resistance, and the NTA was measured at 0 lbs.

Conclusions

Based on the statistically supported findings, the following conclusions were made:

1. Arm exercise on the NCS elicited higher metabolic and physiologic responses than the NTA at the same indicator settings.
2. Leg exercise on the NCS and the NTA at the same indicator settings resulted in similar metabolic and physiologic responses.
3. The measured difference in the forward leg resistance between the NCS and the NTA was either metabolically and physiologically insignificant or was offset by other unaccounted for factors.

Recommendations

Based upon the results of this study, the following recommendations for future research were made:

1. Determine the reliability and validity of the NTA and the NCS resistance indicators as they come from the manufacturer by comparing several models of each machine to each other.
2. Develop a way to measure stroke length of arms and legs so that a more accurate measurement of work done can be developed.
3. Create metabolic charts for different populations, such as athletes, the elderly, cardiac participants, men, and women, based on height, weight, and age which would

incorporate varying angles of inclination, speeds or stride frequencies, and arm and/or leg tensions.

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APPENDIX A

HEALTH HISTORY/ACTIVITY PROFILE FORM

HEALTH HISTORY/ACTIVITY PROFILE FORM
Comparison Study of the NordicTrack Achiever
and the NordiCare Strider

Name ______________________ Date __________

Address ______________________________

City ____________ State ________ Zip Code __________

Home Phone ____________ Date of Birth ___/___/___ Age ____
Work Phone ____________ Height ________ Weight ________
In Case of an Emergency, Please Contact ______________
Phone ______________

Please check if you have or have had any of the following:

____ Blood Pressure ≥ 160/90 mmHg
____ High Cholesterol ≥ 240 mg/dl
____ Diabetes Mellitus
____ Chest Pain with Exercise
____ Shortness of Breath
____ Dizziness or Fainting
____ COPD/Asthma/Emphysema
____ Seizures
____ Heart Attack
____ Heart Arrhythmias or Murmurs
____ Claudication with Exercise
____ Orthopedic Problems
Explain ____________________
____

____ Family history of coronary or other atherosclerotic disease, or sudden death in parents or siblings prior to age 55

____ Recent illness or hospitalization
Explain __________
____
____
____

Please list any medications (Prescription and Non-Prescription) that you are presently taking: __________
____
____

Do you currently smoke? ___ Yes ___ No

PHYSICAL ACTIVITY

Check all the activities in which you currently participate:
____ None ____ Walking ____ Running ____ Bicycling
____ Swimming ____ Aerobic Dance ____ Jump Rope
____ NordicTrack ____ Roller Blading ____ X-C Skiing
____ Rowing ____ Stair Climbing ____ Strength Training
____ Other ____________________

How many days of the week do you exercise?
____ None ____ One ____ Two ____ Three ____ Four
____ Five ____ Six ____ Seven

How long do you exercise?
____ None ____ Less than 15 minutes ____ 15-30 minutes
____ 31-45 minutes ____ 46-60 minutes ____ > 60 minutes

What is your intensity level when exercising?
____ HR < 40% MHR ____ HR 40-60% MHR ____ HR 60-80% MHR
____ HR 80-90% MHR ____ HR > 90% MHR
____ Exercise Intensity (EI) < 40% VO_2max or maximal METS
____ EI 40-60% VO_2max ____ EI 60-70% VO_2max
____ EI 70-80% VO_2max ____ EI 80-90% VO_2max
____ EI > 90% VO_2max
____ RPE < 10 ____ RPE 10-12 ____ RPE 13-15
____ RPE 16-18 ____ RPE > 18

Do you experience any discomforts such as shortness of breath, chest or leg pain or dizziness when exercising?
____ Yes ____ No
If Yes, please explain: ________________________________
____

____
I hereby certify that all the above statements provided by me in this form are complete and true to the best of my knowledge. It is my understanding that this information is confidential and will only be used for the expressed purpose of the aforementioned study. Furthermore, I understand that this information will only be used as a screening device for participation in the study, and that minimum criteria must be met before participation will be granted.

Signature ________________________ Date ______________

Witness ________________________ Date ______________

APPENDIX B

INFORMED CONSENT

INFORMED CONSENT
University of Wisconsin-La Crosse
La Crosse, Wisconsin 54601

Project Title: A comparison of metabolic and physiologic responses of exercising on the NordicTrack Achiever and the NordiCare Strider at equivalent work settings.

Principle Investigators: John P. Porcari, Ph. D., Richard G. Suscha

Subject name: ______________________________

You have been invited to voluntarily participate in a research study which will compare the metabolic and physiologic responses of the NordicTrack Achiever and the NordiCare Strider at equivalent work settings. This study is open to males between the ages of 18-40 years who meet the following criteria: 1) be apparently healthy with no cardiovascular, metabolic or orthopedic problems, 2) be on no medications which affect heart rate or blood pressure during exercise, 3) be a non-smoker, 4) be actively participating in vigorous aerobic activity (i.e., exercise heart rate > 60% of maximal, or exercise intensity > 60% of VO_2max (or maximal METS), or RPE > 12) at least 3 times per week for a minimum of 15 minutes.

I, the above named subject have volunteered to be in this comparison study of metabolic and physiologic responses of the NordicTrack Achiever and the NordiCare Strider at equivalent work settings conducted by Richard G. Suscha. I understand that participation in three practice sessions is required before the two required testing sessions may take place. I will meet at the University of Wisconsin-La Crosse Human Performance Laboratory for the three practice sessions, and the two testing sessions. During the practice sessions, I will be required to exercise on the NordicTrack Achiever and the NordiCare Strider for a minimum of 10 minutes each. The purpose of the practice sessions will be to familiarize myself with the equipment and testing protocol. The equipment will include the NordicTrack Achiever and NordiCare Strider, headgear, mouth piece, and nose clip.

For both of the required testing sessions, I will report to the Human Performance Laboratory at the University of Wisconsin-La Crosse. I will be rested and having abstained from food, tobacco, alcohol, and caffeine for at least 3 hours before the scheduled testing session. I understand that I will be randomly assigned to one of eight testing combinations which will dictate the order I perform the NordicTrack Achiever arm or leg test, and the NordiCare Strider arm or leg test.

I understand the arm protocol for the NordicTrack Achiever and the NordiCare Strider will be five continuous stages, each four minutes in duration. The initial stage will be a warm-up with a work load of nine pounds on the legs and zero kilograms on the arms. The successive work loads for the arms will be increased to 1.0 kg, 1.5 kg, 2.0 kg, and 2.5 kg respectively, at the end of every four minutes. The legs will maintain a constant work load of nine pounds throughout. I will be expected to maintain a cadence of 60 cycles/minute as paced by a metronome. During this time, my oxygen consumption will be monitored through the use of a Quinton Q-Plex metabolic cart. This will be accomplished by my breathing through a mouthpiece, so that expired air can be collected and measured. In addition, my heart rate will be monitored with a transmitter strap wrapped snugly around my chest. When I complete the last stage, or until I can not proceed, I will be given a ten minute rest. At this time, I may remove the headgear, mouthpiece, and nose clip, and walk around. Once the rest period is over, I will then be re-equipped with the monitoring devices and begin the leg test.

I understand that the leg protocol for the NordicTrack Achiever and the NordiCare Strider will be four continuous stages, each four minutes in duration. The initial stage, the cadence, the rest period, and the collection devices will be the same as stated above in the arm protocol. But, I understand that the successive work loads for the legs will follow the progression of 13 lbs, 18 lbs, and 22 lbs while the arms maintain a constant work load of zero kilograms. The test will terminate at the end of the last stage, or when I can not proceed.

I understand and acknowledge that the possibility of adverse reactions exist during the testing session. These reactions may include but not limited to: shortness of breath, extreme arm or leg fatigue, chest pain, dizziness, and rarely sudden death. I may feel tired during and/or after the testing session, but any observed abnormalities by the investigator will expedite test termination and emergency action. I understand that it is my responsibility to make known to the investigator any feelings of discomfort, and to disclose such information if so inquired. I also understand that I may freely stop during a test at any time, or withdraw from the study at any time without penalty. All the obtained date will be kept confidential between myself and the two investigators.

I, ____, being of sound mind and ________ years of age, do hereby consent to, authorize and request the persons named above (and co-workers, agents, and employees) to undertake and perform on me the proposed procedure, treatment, research or investigation (herein called "Procedure"). To the best of my knowledge I am not infected with a contagious disease or have any limiting physical condition or disability, especially with respect to my heart that would preclude my participation in the testing sessions or practice sessions. I have read the above document and I have been fully advised of the nature of the Procedure and the possible risks and complications involved in it, all of which risks and complications I hereby assume voluntarily. I hereby acknowledge that no representations, warranties, guarantees or assurances of any kind pertaining to the procedure have been made to me by the University of Wisconsin-La Crosse, the officers, administration, employees or by anyone acting on behalf of any of them. I understand that I my withdraw from the study at anytime.

Signed at ____, this _______ day of _______________, 19___, in the presence of the witnesses whose signatures appear below opposite my signature.

Witnessed by:

________________________________ ____________________

____

APPENDIX C

RANDOMIZATION PROCESS

Randomization

There were two tests with a 10 minute rest period between each test during each testing session. Because of this design, it was the consensus of University of Wisconsin-La Crosse faculty that to minimize the effects of fatigue during any testing sessions, the tests should be an arm test or leg test followed by the other, but not two arm tests or two leg tests in any testing session.

The randomization was based on the elimination of the combination of two arm tests or two leg tests. The result was 8 possible testing combinations which were randomly assigned to the subjects so that each combination had 3 subjects.

The following eight combinations were each assigned to 3 subjects:

NordicTrack Achiever arms = NTarms
NordicTrack Achiever legs = NTlegs
NordiCare Strider arms = NSarms
NordiCare Strider legs = NSlegs

	1	2	3	4
session 1:	NTarms NTlegs	NTarms NSlegs	NSarms NSlegs	NSarms NTlegs
session 2:	NSlegs NSarms	NTlegs NSarms	NTlegs NTarms	NSlegs NTarms

	5	6	7	8
session 1:	NTlegs NTarms	NTlegs NSarms	NSlegs NSarms	NSlegs NTarms
session 2:	NSarms NSlegs	NTarms NSlegs	NTarms NTlegs	NSarms NTlegs

Random Combination Assignments

Combination	Subject	Subject	Subject
1	______	______	______
2	______	______	______
3	______	______	______
4	______	______	______
5	______	______	______
6	______	______	______
7	______	______	______
8	______	______	______

Randomized Combination	Testing Session 1	Testing Session 2
1	NTarms NTlegs	NSlegs NSarms
2	NTarms NSlegs	NTlegs NSarms
3	NSarms NSlegs	NTlegs NTarms
4	NSarms NTlegs	NSlegs NTarms
5	NTlegs NTarms	NSarms NSlegs
6	NTlegs NSarms	NTarms NSlegs
7	NSlegs NSarms	NTarms NTlegs
8	NSlegs NTarms	NSarms NTlegs

APPENDIX D

INDICATOR CHECKING PROCESS

Checking Resistance Indicators

The NordicTrack Achiever and the NordiCare Strider arm and leg resistance indicators were checked with a spring scale after each testing day. The arm ergometer for each device was checked the same way because the resistance systems were basically the same, but the leg ergometer for each device was different; thus, slightly different checking techniques were employed.

Arm Indicator Check

The arm ergometer was set at zero pounds by loosening the tension knob until a reading of zero pounds was seen on the indicator dial when the ropes were pulled alternately at 60 cycles/minute. The visual reference point was from the perspective of the exercising person while standing on the NordicTrack Achiever or NordiCare Strider. A previously calibrated spring balance scale was then attached to the end of the rope where the handle was located and pulled at a constant rate. The value on the scale was recorded to the nearest 0.1 Kg. Successive measurements were recorded at indicator settings of 1.0 Kg, 1.5 Kg, 2.0 Kg, and 2.5 Kg.

Checking Leg Indicator on the NordicTrack Achiever

The resistance of the leg ergometer was first checked at the lowest tension setting. The lowest tension was indicated when the tension knob was loosened until it could not be loosened any further. With the right ski removed, a 36 inch long nylon cord was attached to the rubber roller by a two half-hitch knot. The rope was then wound tightly around by rolling the rubber roller in a clockwise rotation. A spring balance scale was then attached to the free end of the rope and pulled horizontally at a constant rate towards the back of the NordicTrack Achiever. The spring scale reading was taken to indicate the minimum dynamic friction of the leg resistance and recorded to the nearest 0.25 lbs. Next, with the right ski replaced, the principle investigator skied at 60 cycles/minute and turned the tension knob until the resistance scale indicated 9 pounds. The right ski was then removed again and the resistance on the spring scale was recorded as previously described. The process was repeated for indicator settings of 13 lbs, 18 lbs, and 22 lbs.

Checking Leg Indicator on the NordiCare Strider

The resistance of the leg ergometer was first checked with the tension knob loosened until it could not be loosened any further. The foot glides were positioned with the right foot glide toward the front of the machine, and the left foot glide toward the back. Holes were previously drilled by the investigator at the back end of the glides so that an S-hook could be used to connect the foot glides to the spring scale. The spring scale was then attached to the right foot glide, and pulled horizontally at a constant rate towards the back of the NordiCare Strider. The spring scale reading was taken to indicate the minimum dynamic friction of the leg resistance and recorded to the nearest 0.25 lbs. Next, with the S-hook removed, the principle investigator skied at 60 cycles/minute and adjusted the wire marker to indicate the recorded value by the spring scale. This is how the calibration of the resistance scale was checked. Further measurements were made as follows: 1) while skiing at 60 cycles/minute, an indicator setting of 9 pounds, as indicated by the wire marker, was set by turning the tension knob. 2) with the right foot glide towards the front of the machine and the left foot glide towards the back, the S-hook and spring balance scale was attached to the right foot glide. 3) the spring balance scale was pulled horizontally at a constant rate towards the back end of the NordiCare Strider, and the resistance measured was recorded in pounds. 4) the process was repeated for the indicator settings of 13 lbs, 18 lbs, and 22 lbs.

Results of Checking the Indicators

NordiCare Strider = NCS   NordicTrack Achiever = NTA

Arm Indicator Setting (kg)	Spring Scale Measurement of NTA (kg)	Spring Scale Measurement of NCS (kg)
7/15/92		
0	.1	.3
1.0	1.0	1.4
1.5	1.4	1.9
2.0	1.9	2.4
2.5	2.2	2.8
7/17/92		
0	.1	.4
1.0	1.0	1.4
1.5	1.4	1.9
2.0	1.8	2.5
2.5	2.3	2.8

Arm Indicator Setting (kg)	Spring Scale Measurement of NTA (kg)	Spring Scale Measurement of NCS (kg)
7/18/92		
0	0	.3
1.0	1.0	1.3
1.5	1.5	1.8
2.0	1.9	2.3
2.5	2.4	2.8
7/19/92		
0	.1	.3
1.0	1.0	1.3
1.5	1.4	1.8
2.0	1.9	2.3
2.5	2.2	2.7
7/22/92		
0	.1	.4
1.0	1.1	1.4
1.5	1.5	1.9
2.0	1.9	2.3
2.5	2.3	2.8
7/24/92		
0	.1	.4
1.0	1.1	1.4
1.5	1.6	1.8
2.0	2.0	2.3
2.5	2.4	2.7
7/27/92		
0	.1	.3
1.0	1.1	1.4
1.5	1.6	1.9
2.0	2.0	2.3
2.5	2.5	2.9
8/4/92		
0	.1	.3
1.0	1.1	1.4
1.5	1.6	1.9
2.0	2.0	2.4
2.5	2.4	2.8
8/10/92		
0	.1	.3
1.0	1.0	1.3
1.5	1.5	1.8
2.0	2.0	2.3
2.5	2.3	2.8
8/13/92		
0	.1	.3
1.0	1.1	1.4
1.5	1.6	1.9
2.0	2.0	2.4
2.5	2.4	2.8

Leg Indicator Setting (lb)	Spring Scale Measurement of NTA (lb)	Spring Scale Measurement of NCS (lb)
7/15/92		
Minimum Dynamic Friction	1	8
9	9	9
13	13	13
18	18	18
22	22	22
Forward Leg Resistance	0	2.5
7/17/92		
Minimum Dynamic Friction	1.5	8
9	9	9.25
13	13	13.25
18	18	17.5
22	22	21.5
Forward Leg Resistance	0	2.5
7/18/92		
Minimum Dynamic Friction	1.5	8.5
9	9	9.5
13	13	13
18	18	18
22	22	21.5
Forward Leg Resistance	0	2.5
7/19/92		
Minimum Dynamic Friction	1.25	8.25
9	9	9
13	13	13
18	18	18
22	22	22
Forward Leg Resistance	0	2.5
7/22/92		
Minimum Dynamic Friction	1.5	8.25
9	9	9.25
13	13	13
18	18	18
22	22	22
Forward Leg Resistance	0	2.5
7/24/92		
Minimum Dynamic Friction	1.75	8
9	9	9
13	13	13
18	18	18
22	22	22
Forward Leg Resistance	0	2.5

Leg Indicator Setting (lb)	Spring Scale Measurement of NTA (lb)	Spring Scale Measurement of NCS (lb)
7/27/92		
Minimum Dynamic Friction	1.5	8.25
9	9	9.25
13	13	13.25
18	18	18
22	22	22
Forward Leg Resistance	0	2.5
8/4/92		
Minimum Dynamic Friction	1.5	8
9	9	9
13	13	13
18	18	18
22	22	22
Forward Leg Resistance	0	2.5
8/10/92		
Minimum Dynamic Friction	1.5	8.25
9	9	9
13	13	13
18	18	18
22	22	22
Forward Leg Resistance	0	2.5
8/13/92		
Minimum Dynamic Friction	1.5	8
9	9	9
13	13	13
18	18	18
22	22	22
Forward Leg Resistance	0	2.5

INDICATOR CHECK SHEET

Calibration of Spring Scale Date ____________

Weight Hung (kg)	Reading (kg)	Weight Hung (kg)	Reading(kg)
1.0	________	6.0	________
2.0	________	7.0	________
3.0	________	8.0	________
4.0	________	9.0	________
5.0	________	10.0	________

Arm Indicator Check Date ____________

Tension Setting While Operating (kg)	Spring Scale Reading of NT	Spring Scale Reading of NS
0	________	________
1.0	________	________
1.5	________	________
2.0	________	________
2.5	________	________

Leg Indicator Check Date ____________

Tension Setting While Operating (lb)	Spring Scale Reading of NT	Spring Scale Reading of NS
Tension setting open completely (minimum dynamic friction)	________	________
9	________	________
13	________	________
18	________	________
22	________	________
Forward leg measurement:	________	________

Note: The leg measurements were made on the right foot glide of the NordiCare Strider and the right roller of the NordicTrack Achiever. The arm measurements were made on the left arm pulling rope of the NordicTrack Achiever and the right arm pulling rope of the NordiCare Strider.
NordiCare Strider = NS NordicTrack Achiever = NT

APPENDIX E

CALCULATION OF WORK RATE

Calculation of Work Rate

The calculation of work done during the arm and leg test was based only on the work done by the legs on the flywheel because a reliable method of measuring work done on the arm resistance device was not developed.

The work done on the flywheel was assumed to be constant during the arm test because a fixed cadence was maintained, and the indicated leg resistance did not change. The arm resistance was increased at the end of each stage during the arm test while the legs maintained a constant work rate. Therefore, the work done by the arms was assumed to increase during the arm test, but it was not measured.

The work done on the flywheel was expected to increase during the leg test because the indicated leg resistance was increased at the end of each stage while the cadence remained the same. The work done by the arms during the leg test was assumed to be at a constant low work rate because the indicted arm resistance did not change, and a fixed cadence was maintained.

The mechanical calculation of work rate involved (1) the indicated leg resistance in kilograms (the gravitational acceleration of 1 kg = 1 kp), (2) the revolutions per minute of the flywheel, (3) the circumference of the flywheel, and (4) a correction factor to account for the mechanical advantage of the flywheel versus the drive roller.

The general equation for the rate of mechanical work:

$$\text{Work Rate(kpm/min)} = \frac{\text{Force(kp)} \times \text{distance(m)}}{\text{time(min)}}$$

The equation for the rate of mechanical work applied to a flywheel:

$$\text{Work Rate(kpm/min)} = \text{Force(kp)} \times \text{Velocity(m/min)}$$

where: $\text{Velocity(m/min)} = \text{distance(m)/revolution(rev)} \times \text{revolutions(rev)/minute(min)}$

The following measured and calculated values from the NordiCare Strider and the NordicTrack Achiever were needed to calculate the rate of mechanical work:

Circumference of NordiCare Strider drive roller...... .122m

Circumference of NordicTrack Achiever drive roller... .19m

Circumference of NordiCare Strider flywheel.......... .585m

Circumference of NordicTrack Achiever flywheel....... .71m

Mechanical ratio of drive roller to flywheel
for the NordiCare Strider........................... .21

Mechanical ratio of drive roller to flywheel
for the NordicTrack Achiever........................ .27

The gravitational acceleration of 1 kilogram of mass equals 1 kilopond. Therefore, the relationship of 1 kg = 1 kp was used, and the indicated resistances were considered forces.

The following were sample calculations using the mean value of revolutions per minute(rpm) at stage 4 of the leg test for both the NordiCare Strider and the NordicTrack Achiever:

NordiCare Strider

Work Rate = 22 lbs X 1 kg/2.2 lbs X .21 X .585 m/rev X
(Kpm/min)
496 rev/min

= 609 kpm/min

NordicTrack Achiever

Work Rate = 22 lbs X 1 kg/2.2 lbs X .27 X .71 m/rev X
(kpm/min)
322 rev/min

= 617 kpm/min

APPENDIX F

FLYER USED TO RECRUIT SUBJECTS

NORDICTRACK ENTHUSIASTS

IF YOU ARE A TRACKER OR ALWAYS

WANTED TO TRY

THEN THIS STUDY IS FOR YOU

A study is being conducted to compare the NordicTrack Achiever and the NordiCare Strider. All healthy males between the ages of 18-40 years are eligible. The benefits of participation will be learning the NordicTrack, improve/maintain fitness through scheduled testing sessions, contributing to the advancement of UW-L research, and an optional maximal exercise test.

A minimum of Two one-hour testing sessions are required with more being required if learning is needed.

The dates of participation will be between July 13 to August 13.

If interested, please call:

Human Performance Lab.......782-8681
(ask for Richard)

Richard Suscha..............784-0237

Richard 784-0237	Richard 784-0237
Richard 784-0237	Richard 784-0237
Richard 784-0237	Richard 784-0237
Richard 784-0237	Richard 784-0237

APPENDIX G

PRACTICE/TESTING INSTRUCTIONS

PRACTICE/TESTING INSTRUCTIONS

With participation in this study, you will be completing 3 practice sessions and 2 testing sessions.

Each practice session will be 20 minutes in duration. During a practice session, you will be exercising on each of the two NordicTrack ski machines for 10 minutes.

You will need to attend the two required testing sessions. Each session will be 1 hour in duration.

The location for all practice sessions and testing sessions will be:

UW-L Human Performance Laboratory
225 Mitchell Hall
(2nd floor on southeast side
of the building)

Prior to the practice sessions and the testing sessions, please adhere to the following instructions:

1. Please refrain from consuming alcohol or caffeinated beverages, using tobacco, or eating food for at least 3 hours before a practice or testing session.
2. Please bring and/or wear comfortable shorts, t-shirt, socks, and gym shoes.
3. Please report on time to the Human Performance Laboratory well rested, and having not performed heavy exercise for 24 hours prior to the practice or testing sessions.

YOUR SCHEDULED PRACTICE SESSIONS	YOUR SCHEDULED TESTING SESSIONS
1. ____________________	1. ____________________
2. ____________________	2. ____________________
3. ____________________	

Please keep these appointments. If for any reason you can not make your arranged session, please call:

Richard.........784-0237   Human Performance Lab...785-8681

I would like to thank you in advance for consideration and participation in my thesis study. Your time and efforts are greatly appreciated.

APPENDIX H

TEST SESSION DATA SHEET

TESTING SESSION DATA SHEET

Name ______________________________ Date ______________

DOB _______ Age ____ Sex ____ Height _____ Weight _____

Temp. ____ Barometric Press. ______ Rel. Humidity ______

RHR ____ Testing Combination ____ Testing Session No. ____

NTlegs/NSlegs **Cadence: 60 cycles/minute**

Stage	Min	Dist	Rev	Arm	Leg	RPE	HR	VO_2	V_E	R
1	1	____	____	0	9	___	___	________	____	____
	2	____	____	0	9	___	___	________	____	____
	3	____	____	0	9	___	___	________	____	____
	4	____	____	0	9	___	___	________	____	____
2	5	____	____	0	13	___	___	________	____	____
	6	____	____	0	13	___	___	________	____	____
	7	____	____	0	13	___	___	________	____	____
	8	____	____	0	13	___	___	________	____	____
3	9	____	____	0	18	___	___	________	____	____
	10	____	____	0	18	___	___	________	____	____
	11	____	____	0	18	___	___	________	____	____
	12	____	____	0	18	___	___	________	____	____
4	13	____	____	0	22	___	___	________	____	____
	14	____	____	0	22	___	___	________	____	____
	15	____	____	0	22	___	___	________	____	____
	16	____	____	0	22	___	___	________	____	____

NTarms/NSarms **Cadence: 60 cycles/minute**

Stage	Min	Dist	Rev	Arm	Leg	RPE	HR	VO_2	V_E	R
1	1	____	____	0	9	____	____	____	____	____
	2	____	____	0	9	____	____	____	____	____
	3	____	____	0	9	____	____	____	____	____
	4	____	____	0	9	____	____	____	____	____
2	5	____	____	1.0	9	____	____	____	____	____
	6	____	____	1.0	9	____	____	____	____	____
	7	____	____	1.0	9	____	____	____	____	____
	8	____	____	1.0	9	____	____	____	____	____
3	9	____	____	1.5	9	____	____	____	____	____
	10	____	____	1.5	9	____	____	____	____	____
	11	____	____	1.5	9	____	____	____	____	____
	12	____	____	1.5	9	____	____	____	____	____
4	13	____	____	2.0	9	____	____	____	____	____
	14	____	____	2.0	9	____	____	____	____	____
	15	____	____	2.0	9	____	____	____	____	____
	16	____	____	2.0	9	____	____	____	____	____
5	17	____	____	2.5	9	____	____	____	____	____
	18	____	____	2.5	9	____	____	____	____	____
	19	____	____	2.5	9	____	____	____	____	____
	20	____	____	2.5	9	____	____	____	____	____