UNIVERSITY OF WISCONSIN-LA CROSSE

Graduate Studies

DEVELOPMENT OF PACING PATTERN IN SIX MINUTE VERSUS FREE RANGE NUSTEP TEST

A Manuscript Style Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Clinical Exercise Physiology

Jyoti Y. Swami

College of Science and Health
Clinical Exercise Physiology

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DEVELOPMENT OF PACING PATTERN IN SIX MINUTE VERSUS FREE RANGE NUSTEP TEST

By Jyoti Y. Swami

We recommend acceptance of this thesis in partial fulfillment of the candidate's requirements for the Degree of Master of Science in Clinical Exercise Physiology.

The candidate has completed the oral defense of the thesis.

Carl Foster, Ph.D. — 5/14/12 Date
Thesis Committee Chairperson

Scott Doberstein, M.S., ATC — 5/14/12 Date
Thesis Committee Member

Mark Gibson, M.S., ATC, PT — 5/14/12 Date
Thesis Committee Member

Thesis accepted

Robert H. Hoar, Ph.D. — 5/31/2012 Date
Associate Vice Chancellor for Academic Affairs

ABSTRACT

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The aim of this study was to determine whether the provision of fixed workload (e.g. distance) feedback alters pacing strategy, heart rate, and perceived exertion in a Free Range NuStep trial (FRNST) compared to a fixed 6-minute Nustep trial (6MNST). Nine patients completed 6MNST and FRNST before and after a phase II cardiac rehab program. Pacing pattern was relatively even in the 6MNST and unchanged between pre- and post-trials. The established pacing pattern in the FRNST mirrored that of athletes. Average MET values were significantly improved in both post-trials ($p < 0.05$) and a higher overall exercise intensity was observed in the FRNST. In the 6MNST average METs improved from 3.0 ± 0.66 to 3.5 ± 0.84 and in the FRNST from 3.2 ± 0.70 to 4.0 ± 0.89. Higher peak MET values were achieved during the post-trial FRNST (6.0 ± 2.16) as compared to all other trials. This data supports the ability of the NuStep to track the recovery process during phase II as well as development of pacing pattern across the successive trials.

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Most importantly, I am thankful to my husband for giving me support this whole year when it was hard for me to live without him. He always encouraged me. I will never be able to repay what he has done for me. I feel very lucky to have life partner like him.

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INTRODUCTION

Cardiac rehabilitation (CR) programs are useful for recovering physical, social, psychological, emotional and vocational function in patients with clinical manifestations including myocardial infarction, coronary artery bypass graft (CABG), congestive heart transplantation, angina pectoris, peripheral vascular disease, valvular repairs and a variety of other cardio-pulmonary-metabolic diseases. Of the five phases of CR, phase II is particularly critical because some apprehension may exist due to the early stage of the healing process. Although maximal exercise testing is the preferred method of determining a patient's cardiorespiratory capacity (Bubolz et al., 2003), it is not widely used to measure functional exercise capacity due to pragmatic issues (Soine, 2007).

The submaximal six minute walk test (6MWT) is an important tool to measure functional exercise capacity and prognosis in patients with cardiopulmonary diseases (Lipkin, et al., 1986). It is also a useful outcome measure for tracking recovery. Hence, the 6MWT is an important tool in phase II CR programs because it is inexpensive, easy to interpret and safe compared to a maximal exercise testing. However, there are some limitations to the 6MWT as it is difficult to perform in patients with orthopedic and neurological problems. Also, patient performance is restricted due to the ceiling effect that walking is mechanically limited at speeds < 4.0 mph. The ceiling effect results from the limited pace and stride length of walking, regardless of an individual's ability to perform further cardiovascularly. This causes problems in measuring the changes in functional exercise capacity (Wu et al., 2003).

To overcome these limitations, the NuStep 4000 Recumbent stepper (NuStep Inc., Ann Arbor, MI) developed an alternative strategy for 6MWT that removes ambulatory limitations and ceiling effects (Soine, 2007). The NuStep 4000 is a seated stepper that delivers a complete body workout by combining a stepping motion for legs with coordinated movement for the arms. Specific adjustment of step rate, step depth, and resistance can be made to accommodate comfort and exercise capacity. Early experience with the NuStep 4000 suggested that metabolic equivalent (MET) values were over predicted by the computerized console on the machine. This observation triggered the development of new regression equations to improve MET measurements on the NuStep. Rateike (2000) compared values of measured METs with console values of NuStep and confirmed the difference between predicted and observed values. Based on these findings, a regression equation was developed to more accurately predict METs on it. Paschke (2000) cross-validated Rateike's (2000) findings. He observed that the correlation between actual and predicted values was $r = 0.91$, the standard error of the estimate was 0.38 METS, and the total error was 0.41 METS. These findings demonstrated that the new regression equation provided accurate estimates of metabolic cost, which is useful for professionals in prescribing workloads on the NuStep in CR units. Bubolz et al. (2003) compared the average values of METs of the six Minute NuStep Test (6MNST) with 6MWT for three trials, and found that the reliability coefficient averaged $r = 0.92$ and the predicted accuracy of 6MNST was equal to 6MWT.

Foster et al. (1995) observed that evaluation of objective and subjective scores of exercise tolerance was important to determine the outcome of recovery during exercise based rehabilitation programs. He demonstrated that the time course of change in several outcome measures was potentially important in patients recovering from acute cardiovascular clinical episodes.

Factors which affect exercise performance in the 6MWT are the person's exercise capacity, encouragement (Guyatt et al., 1984), learning effects (Wu et al., 2003), and the pacing strategy which is used to optimize performance and prevent catastrophic failure of physiological systems (St Clair et al., 2006). Past experience with similar activities and prior information of endpoint also influence performance (Foster et al., 2012a). The literature on pacing strategy has recently been reviewed by Foster et al. (2012b). The majority of research on pacing strategy has been completed in healthy athletic individuals and has demonstrated that how a task is paced depends on the presence of a pre-exercise template and on feedback from afferent receptors to the motor control center. Pacing is also subject to learning effects (Foster et al., 2009), with a clear pattern of holding back or "exercising with reserve" (Swart et al., 2009) until a task is learned. The first evidence of learning a pacing pattern in cardiac patients shows evidence of the same pattern (Foster et al., 2012b).

There has been limited research done to track reliability, validity and the ability to track changes in exercise performance with multiple NuStep trials in phase II CR. The aim of this study was to test the hypothesis that phase II CR produces a gradual increase in 6MNST performance across multiple trials. A second hypothesis was that a free range test, with a fixed amount of work to accomplish reveals evidence as to how cardiac patients learn pacing strategy.

METHODS

Subjects

Nine patients who were enrolled in phase II CR at Gundersen Lutheran Medical Center in La Crosse, WI volunteered for this study. The University of Wisconsin-La Crosse and Gundersen Medical Foundation Institutional Review Boards for the Protection of Human Subjects approved the protocol prior to collection of data. Patients provided a written informed consent (Appendix A) prior to data collection.

Protocols

Each subject completed pre- and post-testing of two different tests: the 6MNST and a Free Range NuStep Test (FRNST). The pre-tests were administered during week one of phase II CR. The post-tests were administered during the last week of phase II CR, approximately six weeks later. The 6MNST and FRNST pre- and post-tests were performed in random order on separate days of the week. The patients were not provided any practice trials and testing was administered before beginning other prescribed exercise on the day of testing. Age, weight, height, diagnosis and a list of most current medications were reported prior to testing. Blood pressure was measured at the beginning and end of each test. Persons trained in CPR were present for all trials.

In both types of tests, subjects were allowed to self-select step resistance, step depth and step cadence. During the post-test, the patients were asked to increase the resistance to stepping by at least one level up to whichever was comfortable. The patients were allowed to rest and resume exercise as needed during the test. During both types of tests, the subjects were instructed to perform as much work as possible, following the recommendation of the American Thoracic Society for the 6MWT (American Thoracic Society, 2002). Patients were encouraged by standard statements like, "Keep up the good work" and "You are doing good." The Rating of Perceived Exertion (RPE), heart rate (HR), and kilocalories (kcals) completed were recorded every minute during the 6MNST. The Borg 6-20 scale was used to rate perceived exertion (Borg, 1998). Heart rate was measured using Scottcare Advantage (TeleRehab Advantage Scottcare Corporation, Cleveland, OH) telemetry units. During the FRNST test, time was recorded every two kcals until 30 kcals were achieved. The 30 kcal endpoint was chosen based on pilot data in which patients achieved approximately 30 kcal during 6MNST. Heart rate and RPE were recorded every minute. The average kcals of each test were converted to metabolic equivalents (METs) in order to determine improvements in exercise capacity over the course of phase II CR and to allow analysis of the pacing pattern in both 6MNST and FRNST.

Statistical Analysis

Descriptive statistics were used to characterize the patient population and summarize the results of the pre- and post-6MNST and FRNST. A multiple regression equation was used to predict Watts and allow conversion to METs. A MANOVA was conducted to analyze the differences between pre- and post-test variables. The significance level was set at $p < 0.05$.

RESULTS

The descriptive characteristics of the patients are summarized in Table 1. Nine patients volunteered for the study: 6 males, 3 females. The referring diagnosis for the subjects included: Coronary Artery Bypass Graft = 1, Coronary Artery Stent = 4, Percutaneous Transluminal Coronary Angioplasty = 1, Aorotic Valve Replacement = 1, Combined = 2. The percentage of subjects on cardiac medications included: beta-blockers = 78%, aspirin = 44%, anti-lipidemic agents = 78%, anti-coagulants = 22%, ACE inibitors = 44%, nitrates = 56%, diuretics = 33%, calcium channel blockers = 22%, smoking cessation agents = 11%, diabetic medications = 11%. Medications remained constant during the period of study.

Table 1. Descriptive characteristics of the subject population (N=9)

	Overall (9)	Males (6)	Females (3)
Age (years) (range)	61.6 ± 12.02 (44-83)	62.7 ± 10.78 (44-73)	76. 0 ± 10.44 (64-83)
Weight (kg) (range)	100.4 ± 29.18 (61.8-128.3)	109.6 ± 24.47 (63.2-128.3)	82.0 ± 33.86 (61.8-121.1)
Height (cm) (range)	173.5 ± 8.43 (155.0-183.0)	178.2 ± 3.02 (175.0-183.0)	164.2 ± 8.09 (155.0-170.0)

The average pre- and post-test values for the 6MNST and FRNST are summarized in Table 2. This includes time, kcal, Watts, METs, HR and RPE. Peak values for the respective tests are also presented in Table 2. Because of the large differences in body size amongst the subjects and the known close relationship between body weight adjusted exercise capacity (METs) and the clinical impression of exercise capacity, we chose to use METs as the primary exercise capacity outcome measure for analysis.

During the data collection, kcals were recorded directly from the NuStep 4000. Metabolic equations were used to convert from kcals to Watts to METs (Rateike, 2000; Paschke, 2000).

Table 2. Average values for Pre- and Post-test results of 6MNST and FRNST

	6MNST	6MNST	FRNST	FRNST
	Pre	Post	Pre	Post
Time	6.0 ± 0.00	6.0 ± 0.00	6.6 ± 1.98	5.7 ± 2.16
kcal/min	4.6 ± 1.11	5.6 ± 2.38	5.0 ± 1.83	6.4 ± 2.66
Average Watts	85.5 ± 21.01	97.6 ± 32.97	90.7 ± 27.97	109.4 ± 34.40
Average METs	3.0 ± 0.66	3.5 ± 0.84	3.2 ± 0.70	4.0 ± 0.89
Average HR	95.8 ± 21.88	99.7 ± 23.56	90.2 ± 17.62	93.3 ± 19.49
Average RPE	11.7 ± 1.13	12.6 ± 1.13	11.8 ± 1.51	12.6 ± 1.45
Peak METs	3.7 ± 0.93	4.1 ± 0.94	4.1 ± 0.94	6.0 ± 2.16
Peak Watts	100.6 ± 17.02	110.2 ± 32.79	110.8 ± 33.69	137.8 ± 45.17
Peak HR	103.2 ± 25.66	108.3 ± 26.99	96.4 ± 19.79	104.0 ± 24.36
Peak RPE	12.6 ± 1.21	13.5 ± 1.94	12.7 ± 1.56	13.4 ± 1.73

Improvements in functional capacity were evident by improvements in METs which account for both exercise capacity and body weight (Table 2). The average METs for pre- and post-phase II CR improved in both the 6MNST as well as the FRNST.

Significant differences in the time required to expend 30 kcal during the FRNST were observed pre- and post-phase II CR. The patients required less time to expend 30 kcal during the FRNST.

Average HR for pre- and post- was not significantly different during 6MNST and FRNST. Average peak HR for post- was 108.3 ± 26.99 and 104.0 ± 24.36 beats per minute (bpm) in the 6MNST and FRNST, respectively. This is greater than the pre-average peak HR of 103.2 ± 25.66 and 96.4 ± 19.79 for the 6MNST and the FRNST, respectively.

Average RPE for post- was 12.6 ± 1.13 for the 6MNST and 12.6 ± 1.45 for the FRNST. This was significantly greater than pre- values for RPE: 11.7 ± 1.13 and 11.8 ± 1.51 for 6MNST and FRNST, respectively. Thus, improvement in functional capacity after phase II CR was observed in both test types.

A second goal of this study was to determine differences in pacing strategy before and after phase II CR. Pacing strategy is illustrated in Figure 1.

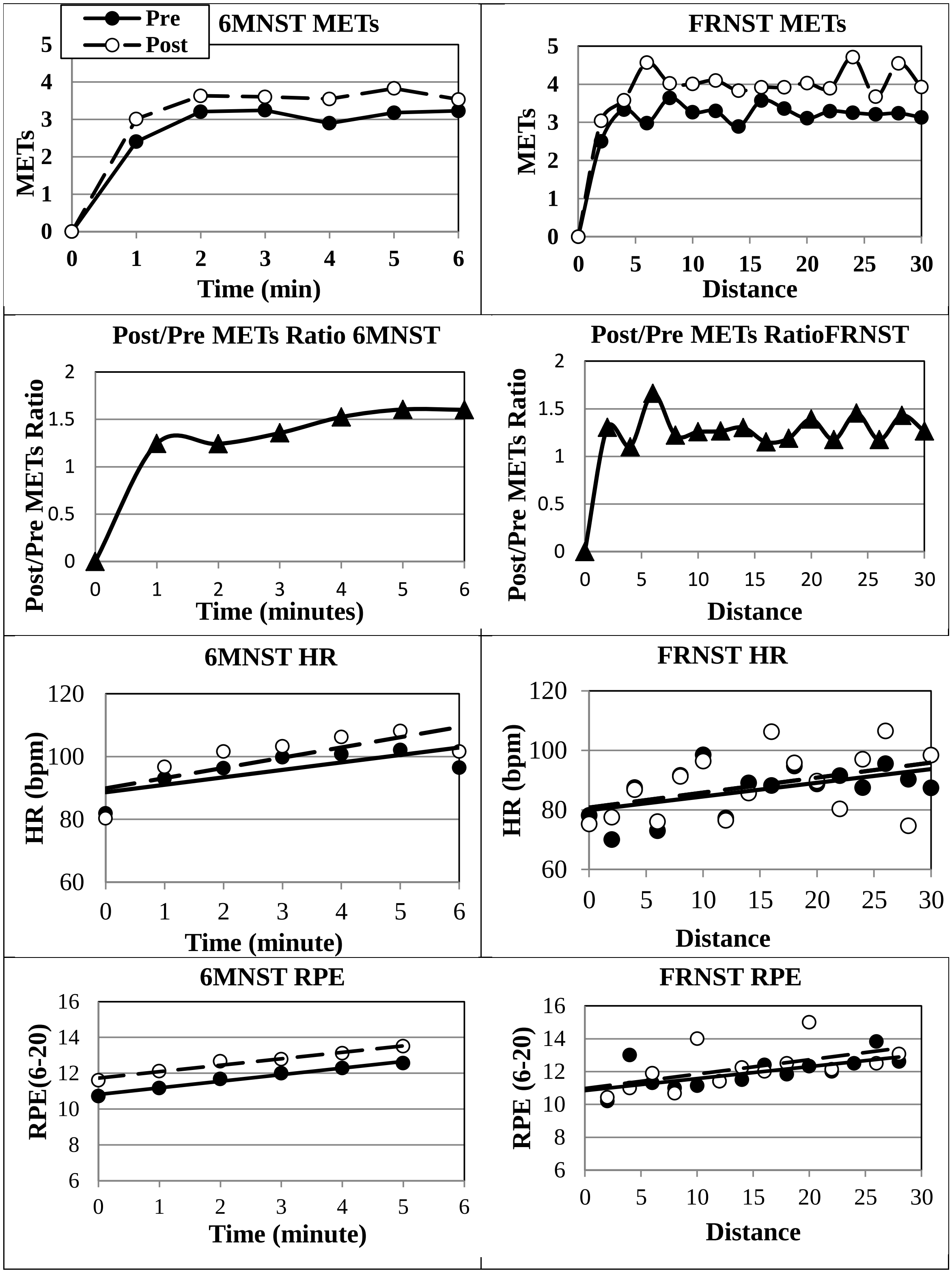

Figure 1. Average values for Pre- and Post-test results of 6MNST and FRNST

Based on Figure 1, it can be concluded that there is no significant difference in pacing strategy before and after phase II CR in the 6MNST. The only difference was a constant higher value for METs from pre to post. This was also evident for HR and RPE. There was a significant difference in pre- and post- pacing strategy for the FRNST. During the pre-test, average METs varied. This pattern continued until the relative distance of 20 kcal, 66% of the FRNST, was reached. From this point forward, patients performed at a constant intensity of 3.2 METs until the completion of the test. Differently, during the post-test, patients initially performed the test at overall higher METs. Patients started from 3.5 METs and reached 4.5 METs. Through the intermediate duration of the relative 30 kcal distance, patients worked at a constant 4.0 METs. The intensity then abruptly increased and reached a peak of 4.8 METs during the last 33 % of the FRNST trial. The post/pre METs ratio for the 6MNST increased linearly from 1.2 to 1.6. The peak post/pre METs ratio was 1.7. The 6MNST has a continuous pattern of ratio whereas the FRNST pattern was more variable.

The pacing strategy also differed between test types. The pacing strategy for the 6MNST had an initial increase in power output (PO) for both the pre- and post-tests and then was constant throughout the remainder of the test. The FRNST pre-test PO varied until 66 % of the relative distance was achieved and then it increased for the remainder of the test. For the FRNST post-test, PO increased during the first 25 % of relative distance increased. Power output then decreased and became constant for the middle 50% of relative distance. In the final 25% of relative distance the PO again increased before returning to the initial starting value.

The RPE was statistically different between pre- and post- of the 6MNST. It increased linearly during both trials of 6MNST and FRNST. There was no significant difference between HR for the 6MNST and for the FRNST. During 6MNST, this was observed in pre- and post-tests.

DISCUSSION

The primary aim of this study was to determine whether the provision of fixed workload FRNST (e.g. distance) feedback alters pacing strategy, HR and RPE compared to a 6MNST. The most important findings were a higher overall exercise intensity in METs during the FRNST compared to the 6MNST and the evidence of a definite pacing pattern in the FRNST that was different than the relatively even intensity pattern seen during the 6MNST.

The pattern of intensity distribution for the 6MNST appeared fixed throughout the exercise, as if it was determined by a pre-exercise template established before the test. This is consistent with the observation by Foster et al. (2009) that pacing strategies influenced by pre-exercise templates are resistant to change. Exercise prescription during phase II CR may be partly responsible for development of this template observed in the 6MNST. Usually patients are being prescribed workloads on the NuStep in fixed time allotments. However, the FRNST to 30 kcal is a novel task for patients, but much more like real world ambulatory tasks, which almost always are defined by finishing a certain amount of work rather than maximizing work in a certain time period. During the FRNST, subjects appeared to change their pacing strategy. In the pre- FRNST, patients initially increased exercise intensity at the onset of the test, but then appeared to 'hold back' on the intensity through the middle and end of the test. During the post- FRNST, the initial increase in energy expenditure and workload was maintained for a longer relative distance before settling into a steady pace preceding a closing 'endspurt.' This supports the velocity curve typically observed in athletes during competition and observed in one study of the 6MWT in cardiac patients (Foster et al., 2009; Foster et al., 2012b). Visual feedback with the end of the test "in sight" may be responsible for developing pacing strategy during FRNST for 30 kcal. Recently Foster et al. (2012b) observed that, similar to athletes, cardiac patients learn a pacing strategy for novel tasks based on completion of successive trials.

It has been suggested that pacing strategy implemented during self-paced exercise is regulated in a subconscious feedforward manner (St Clair Gibson et al., 2001; Ulmer, 1996). Ulmer (1996) suggested that initial exercise intensity is set by feedforward commands and this initial intensity is adjusted during the remaining exercise by a process called teleoanticipation. In this process, intensity is adjusted by either physiological or external stimuli. This supports the observation by Foster et al. (2012b) that the surge, 'endspurt,' occurring at the end of an event with a relatively decreased energy expenditure in the middle part of exercise is attributable to the patient actively regulating energy expenditure (pace) to preventing falling into a catastrophic state (e.g. unacceptably large homeostatic disturbances).

This explanation is substantiated by markers of intensity in the present study: HR and RPE. The average HR for FRNST remained in the range of 80–100 bpm for both pre- and post- tests and increased beyond 100 bpm from the pre-test to post-test 6MNST. There was little difference between average peak HR during the 6MNST and FRNST, and HR increased linearly for both tests. Furthermore, the average RPE did not change for either the 6MNST or FRNST, remaining in range of 10-12. This indicates that patients worked at the same intensity for all trials of both types of tests. Patients did not work harder than regular exercise sessions, possibly regulating pace so to prevent adverse homeostatic disturbance.

During FRNST, when exercise intensity was increased at the onset of the test, RPE increased linearly. While intensity decreased and became constant for most of the remaining relative distance (kcal), RPE continued to increase progressively. This supports the findings of Faulkner et al. (2008) that illustrated a scalar linear relationship of RPE with time despite elevated running velocity, HR response and kcals during competitive running races. For this reason, it appears that RPE is dissociated from the energy expenditure, as the changes in intensity over time were not tracked by the changes in RPE (Albertus et al., 2005).

In summary, data analysis from the current study suggests that a learning effect occurred during the post-phase II trial of the FRNST. The pattern of energy expenditure during the post-test shows an increased rate of energy expenditure at the beginning and end of the post-test. The performance improvement for the post-test may be attributable to better optimization of the pattern of power distribution. During the 6MNST, the pattern of energy expenditure increased initially and became constant for the remainder of testing. Pacing strategy was not altered during the 6MNST, demonstrating the anticipatory feedback mechanism.

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APPENDIX A

INFORMED CONSENT

Title: Comparison of the 6MWT and the 6minute Nu-step Test as an Assessment Tool of Recovery in Phase II Cardiac Rehabilitation

Principal Investigators: Ashley Loftus & Jyoti Swami

Purpose:

- The purpose of this study is to determine the efficiency of the 6 MWT compared to the 6 minute Nu step test to measure the course of recovery in phase II cardiac rehab patients and to compare substantially equivalent time based and distance based test responses..

Procedure:

- This study will require participants to perform a 6 minute walk test; 500 m timed walking test, a 6 minute Nu step test and a Nu Step test with a fixed workload at the beginning, and end of a cardiac rehabilitation program.
- During the trials subjects will be asked to perform at least two tests where they cover as much distance/work as possible in a flat 100ft hallway or on a NuStep ergometer in 6 minutes. They will be required to perform substantially equivalent tests where either the walking distance (500m) or total work accomplished (30 kcal) is completed as rapidly as possible.
- While performing these tests subjects will be wearing a telemetry monitor to record heart rate and rhythm. Ratings of Perceived Exertion will also be recorded at each minute interval.
- The time required for this study will be a part of the cardiac rehabilitation program in which the subjects are participating in at Gundersen Lutheran Medical Center. There will be no additional time required outside that already committed to the cardiac rehabilitation program

Risks

- The risks incurred during this study are minimal and not different from those ordinarily experienced during participation in an exercise based cardiac rehabilitation program

- If an emergency occurs, persons with CPR and Advanced Cardiac Life Support (ACLS) will be present. All of the tests will be performed in GLMC and you will be monitored continuously.

Benefits:

- Through participation in this study subjects will be able to track progress and improvement in their recovery progress. There are no other direct benefits to the participants. The results of the study will help to expand the knowledge in the field about functional testing in cardiac rehabilitation, and the course of recovery for cardiac rehabilitation participation.

Confidentiality

- Your identity and the information will remain confidential to the extent of the law. Information that may be used for identification will be kept by the principal investigator.
- Data collected will only be accessible to the principal investigator, faculty advisor, and the cardiac rehabilitation staff at GLMC and only used when necessary for analysis of results.
- Any information used publically will be done only with group data. All information will be coded, and code kept confidential with the primary investigator

Compensation:

- Neither Gundersen Clinic, Ltd. nor Gundersen Lutheran Medical Center, Inc. will pay for expenses incurred because of side effects caused by the study procedures unless an employee caused the harm by inappropriate medical care.
- Please contact the Principal Investigator, Ashley Loftus (507-273-6804), and call 608-782-7300 as well as 1-800-362-9567 in case an injury occurs.

Cost:

- There will be no additional cost for you to pay in order to participate in this study outside of the fees you are already paying to participate in cardiac rehabilitation.

Voluntary Participation and Withdrawal:

- Your decision to take part in this study is voluntary. You may decide not to take part, or stop taking part at any time, without penalty or loss of benefits to which you are otherwise entitled. If you choose to not participate in the study you may continue to participate in the cardiac rehabilitation program as prescribed by your physician.

Contact Persons:

- For more information regarding the research and research-related risks or injuries, contact the Principal Investigator, Ashley Loftus at (507)-273-6804 or Jyoti Swami at (608)-250-9820 or their faculty advisor Carl Foster PhD. at (608)785-8687. After 5pm, or if you are unable to reach the Principal Investigator, contact the Nurse Advisor at 608-775-4454 or 1-800-858-1050. Tell the Nurse Advisor that you are on a research study and that you may need to be connected to the cardiologist on call. For more information about your rights as a research participant, contact Bernard J. Hammes, PhD, Chair of the Gundersen Lutheran IRB(which is a group of people from the La Crosse area who review the research to protect your rights), at (608) 782-7300 or 1-800-362-9567.

Statement of Consent:

I have read and understand this consent form. All my questions have been answered. I volunteer to take part in this study. I will receive a signed copy of this consent form.

______________________________________ ____________________

Participant Signature Date

______________________________________ ______________

Signature of Researcher obtaining consent Date

____ has read and signed this consent form and told us there are no questions that have not been answered by the researcher. The participant says the consent form is understood and the consent is willingly given. We are writing our names below as witnesses, and we believe the patient understands what is being done and has willingly signed the consent form.

____ ______________________

Witness Signature Date

APPENDIX B

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The aim of this paper is to review the literature regarding the development of pacing strategy during the six minute NuStep Test (6MNST) and the free range NuStep Test (FRNST) by using the NuStep 4000 (NuStep Inc., Ann Arbor, MI). The differences that occur when patients are provided a free range of exercise against a six minute timed trial will be reviewed. Also this review will examine the observed advantage of Nustep over walking as a means of testing pacing strategy. Another aim is to review the reliability and validity of submaximal tests on the NuStep 4000 machine in order to track the recovery process in cardiac population during phase II cardiac rehabilitation (CR) program in contrast with 6MWT.

Cardiac rehabilitation is an exercise based program consisting of four phases. Phase II is most important due to anxiety and depression that may persist as a consequence of incomplete healing processes. Therefore, it is crucial to keep track of the recovery process in phase II CR programs. The 6MWT is frequently used to assess functional exercise capacity because it is easy to administer, inexpensive, and similar to activities of daily living (Lipkin et al., 1986).

Functional exercise capacity is an important predictor of prognostic values more than any other established risk factors in patients with cardiovascular diseases (Myers et al., 2002). The 6MWT can be performed by many elderly, frail and debilitated patients with cardiovascular or lung disease (Enright et al., 2003). Although 6MWT has all the above benefits, it is difficult to administer in patients with orthopedic and neurological problems. Furthermore, limited walking pace and stride length restrict an individual's ability to increase performance. Hence, an individual cannot increase their speed or length of walking after certain limits (ceiling effect).

Furthermore, in the study conducted by Opasich et al. (2001), 315 chronic heart failure patients underwent a functional evaluation and a 6MWT for a period of six months. The walked distance was 396 -/+ 92 m in moderate to severe chronic heart failure patients. There was no significant correlation between distance walked during the 6MWT test with cardiac function and only a moderate correlation to exercise capacity indicators were observed. Functional capacity, as measured by ergometry, correlated moderately with distance walked (duration: $r= 0.48$, peak VO_2: all $p<0.001$; anaerobic threshold: $r=0.54$). Survival analysis was performed from the continuous walk test and peak maximal oxygen consumption (VO_2) measurements. The association of the walk test with survival was not significant; however, peak VO_2 was constantly significant. Thus, the conclusion was that in the population of moderate to severe chronic heart failure patients, the 6MWT is less useful to assess functional capacity.

In a study conducted by Lucas et al. (1999), a population of advanced heart failure patients demonstrated that the 6MWT distance was not a close indicator of aerobic capacity when measured during peak sustained low level exercise. Peak VO_2 after bicycle exercise tests indicated self-determining prognostic information that the 6MWT could not provide in this population. Thus, distance walked in the 6MWT could not predict survival. To overcome these limitations, the NuStep 4000 Recumbent stepper developed an alternative strategy to the 6MWT that corrected ambulatory limitations and ceiling effects (Soine, 2007).

NuStep 4000 recumbent stepper:

The NuStep is commonly used in the field of CR. It is a seated stepper that provides a complete body workout by delivering the regular leg press motion for the legs with coordinated movement for the upper arms. Specific adjustments to step rate, step depth and resistance (exercise workload) can be made according to a patient's comfort and predicted metabolic equivalent (MET) level. It is easy to adjust and make suitable with the physical dimensions (seat depth and arm handle length) of every patient. There has been limited research done to track reliability, validity and ability of the device to track changes in exercise performance with a 6MNST test in phase II CR.

Ability of NuStep to measure MET values:

Metabolic equivalents are frequently used to determine exercise workload. One MET = 3.5 ml O2/kg/min or the amount of oxygen the average person utilizes at rest. There is a linear relationship between exercise intensity and both VO_2 and MET levels. Early studies were observed that MET values as determined by the computerized console on NUStep are over-predicted at any given workload (watts). These values were generated by a regression equation built into the computer software of the machine. Rateike (2000) conducted a study in which he compared the METs values on the console of the NuStep to measured values and developed a regression equation to accurately predict METS. He recruited 50 volunteer subjects between the ages of 43-85 years who had cardiovascular disease, pulmonary disease, or multiple risk factors for the same disease. During the experimental testing, it was found that with minor variations in step depth, resistance, and cadence oxygen consumption, METs was similar at any power outputs (W) regardless of how the workload was achieved. Therefore, subjects were allowed to select any level of the above variables. Subjects exercised with a starting range of 25 or 50 W and increased workload by 25 or 50 W per stage. Each stage was five minutes in duration. Subjects stopped when they achieved a target heart rate (HR) or a rating of perceived exertion (RPE) of 15 on the 6-20 Borg Scale (Borg, 1998). He compared the data of actual METs values versus the console values and the result of the study was that NuStep over predicted actual MET values by 44-73%. Thus, based on these observations Rateike (2000) developed a new regression equation to predict MET values more accurately. Paschke (2000) cross validated the regression equations developed by Rateike (2000) and demonstrated that the equations were a better estimation of METs.

Reliability and validity of submaximal test on the NuStep TRS 4000:

Bubolz et al. (2003) compared the 6MNST with the 6MWT. There were 43 subjects from a phase III and IV CR associated with stable cardiac or pulmonary disease. Each subject performed three trials of the 6MNST and three trials of the standard 6MWT. Average METs were recorded at the end of both exercise tests. Data collected from this study demonstrated that reliable coefficients averaged r = .92 across three trials as well as that the predicted accuracy of the 6MNST was equal to the 6MWT.

Ability of NuStep to measure functional improvement in Phase II Cardiac Patients:

Soine (2007) conducted a study to compare ability of 6MNST versus 6MWT for measuring improvements in functional capacity in phase II CR. During this study, 40 patients from phase II CR performed 6MWT and 6MNT in the first and last week of the program. At the end of both tests, HR, RPE, average MET and average workload was recorded. To measure an improvement in exercise capacity for the entire course of CR, average workout, HR and RPE were obtained from each subject's workout summary from the first and last week of rehabilitation. The initial and final distances were 407 ± 90.5 meters and 442 ± 101.9 meters for 6MWT and 6MNST respectively. On this basis, initial and final functional capacity was 2.9 ± 0.4 and 3.1 ± 0.5 METs respectively. For the NuStep, functional capacity was 2.8 ± 0.7 and 3.5 ± 0.9 METs for pre and post respectively, whereas during the workout it was pre= 2.7 ± 0.8 and post= 4.3 ± 1.8 METs. Although there was a significant improvement in functional capacity for all three measurements, the degree of improvement between each method of measurement was significantly different ($p < 0.05$). Thus the correlations between indices of improvement during rehabilitation were very low in all measures of METs.

Difference in spacing strategy for 6MWT against free Nu Step trial:

There are many studies that have been done on pacing strategy for athletes and a healthy population. Recently, Foster et al. (2012) analyzed a cardiac population to observe if a pattern of pacing strategy develops during 6MWT. It was observed that patients learn pacing strategy for unfamiliar tasks by using past experiences during successive trials. It is really important for prescribing exercise for phase II CR since any new heavy exercise or exercise above the ischemic threshold may lead to myocardial infarction or dysrhythmias. Therefore, they should be advised to use their own pace while they are working to prevent any fatal catastrophic event (Foster et al., 2008).

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