J Rehabil Med 2008; 40: 721–726

**ORIGINAL REPORT**

# RELATIONSHIP BETWEEN WALKING FUNCTION AND ONE-LEGGED BICYCLING TEST IN SUBJECTS IN THE LATER STAGE POST-STROKE*

Cristiane Carvalho, PT[1], Carin Willén, RPT, PhD[1] and Katharina S. Sunnerhagen, MD, PhD[1,2]

*From the [1]Institute of Neuroscience and Physiology, Section of Clinical Neuroscience and Rehabilitation Medicine, Göteborg University, Göteborg, Sweden and [2]Sunnaas Rehabilitation Hospital and Medical Faculty, Oslo University, Oslo, Norway*

***Objective:*** **The aim of the present study was to examine the correlation between one-legged bicycling and the 6-minute walk test (6MWT) in subjects post-stroke. A further aim was to analyse the relationship between specific stroke impairment and walking endurance.**

***Participants:*** **Thirty-four subjects (mean age 60 (standard deviation (SD) 4.1) years; mean time post-stroke 62 (SD 33) months) with stroke at least 6 months earlier were tested.**

***Methods:*** **Subjects were evaluated using the 6MWT (distance, heart rate, systolic blood pressure), one-legged bicycling ($VO_2$peak, maximal workload (Wmax), heart rate, systolic blood pressure, total exercise time), Fugl-Meyer motor function scale for the lower extremity and Berg Balance Scale. Correlational analyses were used to evaluate the relationships between variables.**

***Results:*** **There was a low correlation between 6MWT and $VO_2$peak (rs = 0.39) and a moderate correlation with Wmax (rs = 0.64) and total exercise time (rs = 0.58) ($p < 0.001$) during one-legged bicycling test for the paretic leg. However, no significant correlation was found in the non-paretic leg. Motor function for the lower extremity and Berg Balance Scale showed a high (rs = 0.72) and moderate (rs = 0.68) correlation, respectively, with the 6MWT.**

***Conclusions:*** **The 6MWT is influenced by motor function and balance as well as cardiorespiratory fitness. Heart rate and systolic blood pressure indicate cardiovascular stress, but the 6MWT cannot be used alone to evaluate fitness in subjects with stroke in the later stages.**

*Key words:* cerebrovascular accident, exercise test, gait, physical therapy, rehabilitation.

J Rehabil Med 2008; 40: 721–726

*Correspondence address: Cristiane Carvalho, Rehabilitation Medicine, Guldhedsgatan 19, 3 floors, Sahlgrenska University Hospital, SE-413 45 Göteborg, Sweden. E-mail: cristiane.carvalho@neuro.gu.se*

Submitted October 16, 2007; accepted May 19, 2008

*This article has been fully handled by one of the Associate Editors, who has made the decision for acceptance, as it originates from the institute where the Editor-in-Chief is active.

## INTRODUCTION

The incidence of stroke increases with age, and the stroke population generally consists of individuals with a high prevalence of cardiovascular disease, physical deconditioning and a sedentary lifestyle (1). Consequently, this leads to a reduction in cardiorespiratory fitness (2–4), which has been correlated with a higher risk for additional strokes and stroke mortality (5). Difficulties in walking associated with hemiparetic gait may lead to increased energy cost, generating a further decline in cardiorespiratory fitness and limiting the individual's daily functional activity and resulting in a poor rehabilitation outcome (4).

Stroke-specific impairments, such as muscle weakness, limb pain, spasticity and balance problems, can cause difficulties in the realization of a standard maximal exercise test; a submaximal exercise test may be better tolerated and, eventually, be a desirable option to monitor levels of cardiovascular fitness in this population (6). Pedalling is a functional activity that can be used by patients after stroke at a very early stage of rehabilitation and has been used as a tool to evaluate aerobic capacity in this population (7, 8). One-legged bicycling has been used as an assessment tool in patients with hemiparesis (9, 10) in order to reduce the effect in the test of the leg with the greatest impairment. Landin et al. (9) showed that there was a difference during one-legged bicycling between sides in terms of blood flow, lactate production and muscle morphology. Oxygen consumption was found to be higher at any given power output during one-legged exercise compared with 2-legged exercise in healthy subjects (11, 12), and the evaluation of each leg separately would probably better assess the effects of training.

$VO_2$peak is considered the "gold standard" indicator in the assessment of cardiovascular fitness. However, this type of test requires sophisticated and expensive equipment and specialized personnel, and is time-consuming (13). The apparatus required is not available in most rehabilitation units and community settings. Walking is a common activity in everyday life. The 6-minute walk test (6MWT) has been found to be a valuable measure of cardiovascular exercise capacity in elderly subjects with respiratory disease and chronic heart failure (14, 15). The distance walked in 6 min in this population has been demonstrated to have a moderate to high correlation

 ISSN 1650-1977
doi: 10.2340/16501977-0242

with $VO_2$peak during bicycle or treadmill exercise tests (16, 17). The 6MWT seems also to reflect everyday activities, since they often require walking. Recent studies have investigated the relationship between endurance exercise capacity ($VO_2$max or $VO_2$peak) and walking capacity (6MWT) in sub-acute patients and those after chronic stroke, but the results are contradictory (6, 18, 19).

The present study was undertaken to examine the correlation between maximal exercise capacity measured during a one-legged bicycling test and the 6MWT in subjects in the later stage post-stroke (> 6 months post-stroke). We hypothesized that the exercise performed with the paretic leg would correlate better than the non-paretic leg with walking endurance since, intuitively, the weak leg limits walking, becoming tired more easily than the non-paretic leg. We also wanted to investigate if the 6MWT was influenced by motor function and balance or if performing the test indoors or outdoors (which perhaps more accurately reflects real life) made a difference.

## METHODS

### *Study participants*

A community-dwelling population of 34 subjects (male and female) older than 50 years of age and at least 6 months post-stroke were recruited for the study. All subjects had been patients at the Rehabilitation Medicine Clinic at Sahlgrenska University Hospital, Göteborg, Sweden. Subjects were included if they could walk for at least 5 min without personal assistance. Assistive devices and ankle-foot orthoses (AFO) were permitted. Exclusion criteria were severe heart disease, uncontrolled hypertension, leg wounds, pain or other than stroke induced gait disability or inability to follow instructions.

The following data were recorded for each participant: gender, age, weight, height, months post-stroke, type of stroke, paretic side, concomitant diseases and ongoing treatment, including beta-blockers. Subjects were asked to continue their usual medication and to refrain from caffeinated drinks and tobacco cigarettes for 2 h before the test.

The study was approved by the ethics committee, Göteborg University, and written informed consent was obtained from all subjects.

### *Study protocol*

The subjects were assessed twice over the course of 2 weeks on separate days. In the first session they were all assessed at the Rehabilitation Medicine Clinic at Sahlgrenska University Hospital by the same physiotherapist. This session included the collection of disease and medical histories and assessment of the Fugl-Meyer Scale for the lower extremity (20), Berg Balance Scale (BBS) (21) and 6MWT (22) in the same order for all subjects. The next session was held at a laboratory, where a one-legged bicycling (10) test was performed. The test was conducted in the presence of a physician, a nurse and a physiotherapist.

### *Physiological measurements and techniques*

*Lower extremity function.* Motor function in the affected lower extremity was assessed according to the Fugl-Meyer Scale (20). This scale is considered by many in the field of stroke rehabilitation to be one of the most comprehensive quantitative measures of motor impairment following stroke, and it has been shown to be valid and reliable (23, 24). The scale consist of a 3-point ordinal scale (0: cannot perform; 1: partially performs; 2: performs fully) in which the summation of the scores from different items gives a maximum score of 34, which indicates normal movement control in the affected side compared with the non-affected side.

*Balance.* The BBS was used to assess functional balance (21, 25). It consists of 14 functional tasks, including ability to sit, stand, reach, lean over, turn in a complete circle and step. The maximal score on the BBS is 56. A higher score indicates better balance skills. The test has been shown to be reliable and valid in this group of patients (26).

*Walking function.* The 6MWT (16) was originally developed to assess cardiopulmonary function. Subjects were given 6 min to walk as far as they could at their usual pace back and forth over a 30 m course. The turn-around points were marked with a traffic cone. The subjects performed the test indoors and outdoors in a randomized order.

The distance covered in 6 min was recorded. The instructions for the test were standardized according to American Thoracic Society (ATS) statement guidelines for the 6MWT (22). At the end of each minute subjects were given feedback on the elapsed time and standardized encouragement in the form of statements such as “you are doing well” and “keep up the good work”. Subjects were allowed to stop and rest as they deemed necessary. The subjects could use their usual orthoses and assistive devices. The subjects wore a heart rate (HR) monitor (Polar F1/F2; Polar Electro Oy; Finland) for continuous HR measurement. At the start and end of the test, HR, blood pressure (only systolic blood pressure (SBP) was analysed) and rating of perceived exertion (Borg CR 10 scale) (27) were noted. This test has been used extensively to monitor function in individuals with cardiopulmonary problems and has been used recently by researchers studying individuals after stroke (18, 28, 29), but its reliability or validity has not been established in this population.

*Cycle Ergometer Exercise Test.* Peak oxygen uptake ($VO_2$peak) and maximal workload (Wmax) were measured on an electrical bicycle ergometer (CCE 2000 Medical Graphic Corporation St Paul, MN, USA) to evaluate cardiorespiratory fitness. Since the $VO_2$max measurement can sometimes not be achieved by an unfit and elderly population (30), we chose the highest, or peak, level of oxygen consumed ($VO_2$peak), to measure aerobic capacity. The exercise test was conducted testing each leg separately (10). The exercise started at 0 W after the individual had become familiar with the equipment and had been pedalling for 3 min without friction resistance. Subsequently, a ramp protocol with 10-W/min step-less increment was used. The pedalling rate was approximately 60 revolutions/min and the workload was maintained by the computer program controlling the bicycle. The maximal workload was the highest workload maintained for at least 30 sec. Breath-by-breath gas exchange was recorded on-line by measuring the expired gas flow and expiratory oxygen gas meters via a facial mask (Medical Graphic Corp., St Paul, MN, USA). The electrocardiogram, HR and blood pressure were monitored during the test. The individual perceived exertion was measured on the Borg category ratio scale (Borg CR 10 scale) (27) with exponential increments from 0 to 10. The exercise test duration was also noted and was the total time in sec from the start of the test until the subject stopped pedalling. The reliability of the method for assessing oxygen consumption in a stroke population has been established in a previous study (10). The test order of the non-paretic and the paretic leg was randomized. Subjects cycled with 1 leg while resting their non-working leg on a pillow placed in front of them on a stool. The exercising leg was fastened securely to the pedal with both the clip and Velcro straps. This position was quite comfortable and was immediately accepted by the participants without practice or need for any position adjustments.

There was a rest period before recommencing the test with the other leg. The subjects were required to rest, sitting in a chair, and were offered water to drink. Their blood pressure was followed to assess normal values. Their HR was monitored and the test only resumed once it had returned to a resting level. This usually took between 5 and 7 min.

The guidelines provided by the American College of Sports Medicine were used to determine whether the test should be terminated prematurely (13). Subjects were also asked to identify the reason for stopping, e.g. leg pain, feeling a loss of muscle strength, generalized fatigue or other reasons.

Peak HR achieved at both tests (6MWT and cycle test) was expressed as a percentage of the age-predicted HR maximum (220 beats/min minus age in years) (13).

*Statistical analyses*

Data are expressed as the mean and standard deviation (SD) for continuous variables and median and range for the non-continuous variables. To test our hypothesis, the Spearman's rank correlation coefficient (rs) was used to describe the correlation among the different variables, as follow: (1) 6MWT distance and (*i*) one-legged bicycling values ($VO_2$ peak, Wmax, total exercise time) and (*ii*) impairment measures (Fugl-Meyer scale and BBS); (2) Impairment measures and one-legged bicycling values; (3) $VO_2$ peak and (*i*) HR and (*ii*) SBP at the end of the 6MWT and (*iii*) the change achived in HR and SBP during 6MWT. The strength of the correlation was defined by the correlation coefficient obtained: 0.26–0.49, low; 0.50–0.69, moderate; 0.70–0.89, high; and 0.90–1.00, very high (31). The Wilcoxon signed-rank test was used to analyse pre- and post-test HR and SBP during the 6MWT (indoor/outdoor) and one-legged bicycling (paretic/non-paretic leg). We used the same statistical test to identify whether the different tests have the same or a different influence on the HR and SBP. Data from subjects who were on beta-blockers were not included in the analyses of changes in pulse and blood pressure. A standard multiple regression analysis was used to assess the influence of impairment measures (Fugl-Meyer scale and BBS) on the 6MWT distance.

All analyses were made using the SPSS computer package (Version 13.0). A *p*-value of 0.05 was considered statistically significant.

## RESULTS

The anthropometric, demographic and medical characteristics of the study group are given in Table I. The 6MWT (indoors and outdoors) was completed with 11 subjects using their usual assistive devices and AFO (rollator, $n=1$; cane, $n=4$; AFO, $n=2$; cane+AFO, $n=4$). All 34 subjects were able to perform the one-legged bicycle exercise test with the non-paretic leg, but only 30 were able to perform the test with the paretic leg. Reasons for stopping the one-legged bicycling test with the paretic leg/non-paretic leg were: leg pain (67/68%), physical fatigue (10/18%), feeling of loss of muscle strength (10/3%), leg pain and physical fatigue (7/6%), feeling of loss of muscle strength and physical fatigue (3/3%). Results of the 6MWT (indoor and outdoor) and one-legged bicycle exercise test (paretic and non-paretic leg) are shown in Table II.

Low to moderate correlations were found between the 6MWT and one-legged bicycling measurements from the paretic leg, such as $VO_2$peak, Wmax and total exercise time (Table III). The 6MWT showed no significant correlation with variables from the non-paretic one-legged bicycling test. The only difference between indoors and outdoors is that 6MWT indoors did not significantly correlate with $VO_2$peak for the paretic leg (Table III).

There was also a correlation between specific stroke impairments and the walking test. The Fugl-Meyer scale for the lower extremity showed a high significant correlation and BBS showed a moderate significant correlation with 6MWT (Table IV). These 2 variables together explained the variance in walking distance achieved indoors (74%) and outdoors (76%).

When specific stroke impairments were compared with variables from the one-legged bicycling, a low significant correlation was found between lower muscle function and BBS with Wmax and total exercise time in the paretic leg (Table III).

No significant relationship was found between $VO_2$peak (paretic and non-paretic leg) and HR and SBP measured at the end of and the change achieved during the walking test.

Mean HR achieved at the end of the 6MWT was about 85% and 83%, respectively, of the peak HR from the maximal exercise test for the paretic and non-paretic leg and 64% of the age-predicted maximal heart rate. The mean peak HR achieved during the one-legged bicycling test was 74% for the paretic and 76% for the non-paretic leg of the subjects' age-predicted maximal heart rate.

Table I. *Subject characteristics*

| | |
|---|---|
| Gender, male/female, *n* | 24/10 |
| Type of stroke, ischemic/hemorrhagic, *n* | 23/11 |
| Paretic side, left/right. *n* | 19/15 |
| Medications, *n* | |
| β-blockers | 15 |
| ACE inhibitors | 11 |
| Calcium antagonist | 9 |
| Cholesterol inhibitor | 17 |
| Co-morbidities, *n* | |
| Cardiovascular disease | 7 |
| Hypertension | 22 |
| Arrhythmia | 4 |
| Diabetes mellitus | 5 |
| Hypercholesterolemia | 9 |
| Smoking history | 6 |
| Age, years, mean (SD) [range] | 60 (4.1) [53–68] |
| Weight, kg, mean (SD) [range] | 79.5 (12.2) [55–109] |
| Height, m , mean (SD) [range] | 1.74 (0.07) [1.59–1.94] |
| Months post-stroke, mean (SD) [range] | 62 (33) [12–159] |
| Fugl-Meyer scale lower extremity, median [range] | 30 [13–34] |
| Berg Balance Scale, median [range] | 51 [35–56] |

ACE: angiotensin converting enzyme; SD: standard deviation.

## DISCUSSION

This study was designed to evaluate the correlation between maximal exercise capacity measured in a one-legged bicycling test and the 6MWT in subjects in the later stage post-stroke. The results differ in important aspects from those of studies reported previously, since the bicycle exercise test was performed with only one leg in our study. In agreement with previous studies (6, 19), we found a poor correlation between $VO_2$peak and the 6MWT distance. In contrast, 3 studies investigating the relationship between the 6MWT distance and $VO_2$peak in subjects with stroke, the results showed high (18) and moderate correlation (32, 33). However, the group tested in these studies was in the sub-acute phase post-stroke and also included younger subjects.

During 2-legged bicycling exercise, both legs are engaged to help with the upward and downward stroke, while during one-legged bicycling exercise, the entire circumference must be performed by only one leg. The exercising muscle mass must thus apply more force throughout the full range of movement (34). According to other studies (10, 35), the results obtained with one-legged bicycling are not equal to half the work per-

Table II. *Results of 6MWT and one-legged bicycling test*

| | $n$ | Mean (SD) | Range |
|---|---|---|---|
| 6MWT, indoor/outdoor | | | |
| Distance, m | 34 | 365.2/ 373.6 (142.6/150.8) | 80–540/90–561 |
| Resting heart rate, beats/min | 34 | 76 / 77 (14/15) | 41–114/40–114 |
| End heart rate, beats/min | 34 | 100/102 (21/21) | 56–146/55–148 |
| Resting systolic blood pressure, mmHg | 34 | 124 /126 (16/15) | 100–160/100–160 |
| End systolic blood pressure, mmHg | 34 | 134/133 (18/18) | 100–170/100–170 |
| Cycle exercise test | | | |
| Paretic leg | | | |
| $VO_2$ peak, $ml \times kg^{-1} \times min^{-1}$ | 30 | 10.7 (5.5) | 2.3–27.3 |
| Resting heart rate, beats/min | 30 | 76 (16) | 47–106 |
| Peak heart rate, beats/min | 30 | 119 (28) | 59–164 |
| Resting systolic blood pressure, mmHg | 30 | 134 (14) | 110–160 |
| Peak systolic blood pressure, mmHg | 30 | 164 (26) | 120–210 |
| Maximal workload, Wmax | 30 | 18 (16) | 0–61 |
| Total exercise time, sec | 30 | 462 (119) | 267–750 |
| Non-paretic leg | | | |
| $VO_2$ peak, $ml \times kg^{-1} \times min^{-1}$ | 34 | 11.6 (6.5) | 5.1–38.2 |
| Resting heart rate, beats/min | 34 | 75 (16) | 45–106 |
| Peak heart rate, beats/min | 34 | 121 (32) | 57–198 |
| Resting systolic blood pressure, mmHg | 34 | 134 (14) | 115–160 |
| Peak systolic blood pressure, mmHg | 34 | 166 (26) | 125–220 |
| Maximal workload, Wmax | 34 | 31 (29) | 3–122 |
| Total exercise time, sec | 34 | 519 (176) | 299–1080 |

6MWT: 6 minute walk test; SD: standard deviation.

formed in a 2-legged bicycling test. As far as we know, we found only studies evaluating $VO_2$peak or $VO_2$max in young healthy males using the comparison between 1- and 2-legged bicycling tests (34–39). Landin et al. (9) tested 9 male patients with moderate hemiparesis using both 1- and 2-legged bicycle exercise, but the criteria for examination were arterial lactate concentrations, leg exchange of carbohydrate, free fatty acids and the concentrations of intramuscular metabolites.

As hypothesized, the one-legged bicycling test performed with the paretic leg correlated better with the 6MWT distance than the non-paretic leg, even though it was a low to moderate correlation. The mean $VO_2$peak, Wmax and total exercise time for the paretic leg were 85%, 77% and 81%, respectively, for the means reached on the non-paretic leg.

Table III. *Correlation between 6MWT, Fugl-Meyer scale and BBS with one-legged bicycling ($VO_2$peak, Wmax and total exercise time)*

| | $VO_2$peak | | Wmax | | Total exercise time | |
|---|---|---|---|---|---|---|
| | PL rs | NL rs | PL rs | NL rs | PL rs | NL rs |
| 6MWT | | | | | | |
| Indoor dist | 0.335 | 0.161 | 0.589*** | –0.004 | 0.530** | 0.190 |
| Outdoor dist | 0.391* | 0.208 | 0.646*** | 0.054 | 0.583*** | 0.235 |
| Fugl-Meyer† | 0.097 | –0.125 | 0.398* | –0.289 | 0.329 | –0.109 |
| BBS | 0.194 | 0.119 | 0.370* | –0.104 | 0.396* | 0.150 |

*$p \leq 0.05$; **$p \leq 0.01$ ***$p \leq 0.001$.
†Fugl-Meyer scale for the lower extremity.
6MWT: 6 minute walk test; dist: distance in metres; BBS: Berg Balance Scale; PL: paretic leg; NL: non-paretic leg; rs: rank correlation.

In our subjects the walking test performance seems to be associated more with specific stroke physical impairments, such as lower motor function and balance, than with cardiorespiratory status. Previous studies in subjects with stroke in the sub-acute (40) and chronic phase (19) reported similar results. These impairments also seem to limit the performance on maximal exercise test more than cardiorespiratory factors, since most participants stopped for non-aerobic reasons, such as leg pain and feeling of loss of muscle strength. However, the increases in HR and SBP during the 6MWT suggest that the walking test did put strain on the cardiovascular system.

Poor cardiovascular endurance has been seen in subjects after a stroke (41–43) as we also demonstrated in our study group. Our study aimed to evaluate the influence of each leg on the cardiorespiratory fitness. In order to compare the results with others studies, it might have also been better to evaluate a 2-legged bicycling test, but this was not done. Based on data from age-matched healthy population (44), we can hypothesized that the mean $VO_2$peak measured during the one-legged bicycling

Table IV. *Correlation between 6MWT and specific stroke impairments*

| | Fugl-Meyer scale† | BBS |
|---|---|---|
| 6MWT | | |
| Indoor dist | 0.721*** | 0.671*** |
| Outdoor dist | 0.744*** | 0.689*** |

***$p \leq 0.001$.
†Fugl-Meyer scale for lower extremity.
6MWT: 6 minute walk test; dist: distance in metres; BBS: Berg Balance Scale.

test with the paretic leg was approximately 32% and with the non-paretic leg 35% of the $VO_2$peak values during the 2-legged bicycling ergometer test. This mean that the aerobic capacity of our subjects was reduced when compared with that from another study of subjects with stroke of similar ages and time post-stroke; the mean $VO_2$ peak values were about 46% for the paretic leg and 49% for the non-paretic leg (19) in comparison with the $VO_2$peak achieved in that study. The results of our study showed that the $VO_2$peak values in our subjects were lower than the values reported to be required for independent living (45). However, our study group lived in the community and had an independent life.

The mean distance (365 (SD 142) m indoors; 373 (SD 150) m outdoors) covered during the walking performance in our study was longer than in other studies (18, 19, 32, 33, 40), except for that of Eng et al. (6) study, in which a mean value of 378.3 (SD 123.1) m was reported in a smaller sample of 12 chronic stroke survivors. Whether this is due to fitness after stroke *per se*, or to sample size, or is reflection of different cultures where walking is more or less common is not clear.

Some limitations of the study must be addressed. First, it would be of value to study a larger group of subjects and perhaps a better correlation would be achieved. Secondly, as the inclusion criteria excluded subjects who could not walk for at least 5 min and without personal assistance, we therefore assume that our study group is more "conditioned" and it may be that our results cannot reflect the cardiorespiratory condition in persons with stroke in general.

This study demonstrated that subjects with stroke showed an important reduction in cardiorespiratory fitness. There is a need to prevent deconditioning and to improve the cardiorespiratory fitness in persons after stroke, not only in the acute and sub-acute phases, but principally in the later stage after stroke when the rehabilitation period has been completed and there is a sedentary lifestyle as a consequence of physical inactivity. An alternative could be community-based exercise programmes (46, 47), in which it has been found that subjects with stroke improve their mobility, fitness condition and functional capacity through group exercise training.

In conclusion the cardiorespiratory fitness and walking function was decreased in this sample of subjects with stroke in the later stage. It seems that factors other than the cardiorespiratory fitness influence the 6MWT. HR and SBP indicate cardiovascular stress, but the use of only the 6MWT distance as an indicator for cardiorespiratory fitness in subjects with stroke in the later stage cannot be recommended.

## ACKNOWLEDGEMENTS

This study has in part been supported by the following organizations: The Swedish Research Council (VR K2002-27-VX-14318-01A), John and Brit Wennerström's Foundation, the Hjalmar Svensson Foundation, the Göteborg Foundation for Neurological Research, Greta and Einar Askers Foundation and the Rune and Ulla Amlös Foundation. We would also like to thank all the participants in the study.

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