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Original Paper

Gait Endurance Index for Patients with Hemiplegia due to Cerebrovascular Accidents

Susumu WATANABE* and Katsushi KUNIYASU*

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Key words : gait endurance, hemiplegia, cerebrovascular accident, index

Abstract

The purpose of this study was to investigate the validity of the gait endurance index (GEI) for easily evaluating the physical fitness of hemiplegic patients. The subjects were 52 hemiplegic patients(39 men and 13 women, 55.1 ± 11.3 years old) and 11 healthy subjects (7 men and 4 women, 64.0 ± 6.1 years old) as a control group. All patients were able to walk indoors without aids or with a brace or cane or both. All subjects were tested using the GEI, which was defined as the gait distance for 5 min. / recovery heart rate. The recovery heart rate was defined as the total number of heart beats during the 1-1.5 min., 2-2.5 min. and 3-3.5 min. intervals just after gait. Oxygen uptake and heart rate were measured with portable equipment during gait in 13 hemiplegics who volunteered to participate and the 11 healthy subjects. The gait distance for 5 min., recovery heart rate and GEI were measured twice in 23 patients during a two week period. The gait distance of the patients was significantly shorter than that of the healthy subjects, but there was no significant difference in the recovery heart rate between the two groups. The GEI of the patients was significantly smaller than that of the healthy subjects. A significant correlation was found between the gait distance for 5 min. and oxygen uptake in the volunteer group, and between the recovery heart rate and the steady state heart rate during gait. No correlation between the recovery heart rate and the gait distance for 5 min. was found, in either the patients or the control group. These results indicate that the GEI is a valid and simple measure of physical fitness for hemiplegic patients after strokes.

Introduction

Exercise testing, using treadmills and bicycle ergometers to measure physical fitness, has been commonly carried out in hemiplegic stroke patients. A patient's maximal oxygen uptake ($\dot{V}O_2$ max), predicted maximal oxygen uptake, and $\dot{V}O_2$ (100) or $\dot{V}O_2$ (120), i.e. , oxygen uptake at a heart rate of 100 or 120 beats / min., are usually used as the parameters of physical fitness [1][2]. The maximal heart rate and a combination of the heart rate and oxygen uptake are also used, since a good correlation exists between oxygen uptake and heart rate [3]. Other researchers in Japan have used the anaerobic threshold (AT) to make an evaluation[4][5][6]. The physiological cost index (PCI), which can be measured easily, is a measure of energy consumption during gait using the heart rate [7][8]. The first problem in evaluating

* Department of Restorative Science, Faculty of Medical Professions
Kawasaki University of Medical Welfare
Kurashiki, Okayama, 701-0193, Japan

Table 1 The gait distance for 5min., the recovery heart rate and the GEI in patients and controls are shown.

	Gait Distance (m)		Recovery Heart Rate (Beats/90sec)		GEI	
Patient	135 ± 57	*	123 ± 22	NS	114 ± 52	*
Control	244 ± 40		132 ± 17		188 ± 36	

* p< 0.01 NS: Not significant (Mean ± SD)

the physical fitness of hemiplegic patients is the difficulty in determining whether their maximal exercise level is limited by their physical fitness or by their motor function disability. The second problem is the difficulty in measuring oxygen uptake at many clinical facilities, because such testing requires expensive equipment and troublesome procedures. The authors developed the "Gait Endurance Index" (GEI) to resolve these problems. The purpose of this study was to investigate the validity of our GEI procedure for the easy evaluation of the physical fitness of hemiplegic patients.

Subjects and Methods

The subjects were 52 hemiplegic stroke patients (39 men and 13 women, 55.1 ±11.3 years old, 49 outpatients and 3 inpatients) and 11 healthy subjects (7 men and 4 women, 64.0 ± 6.1 years old) who participated voluntarily as a control group. Some patients required a brace or cane or both to walk, while others were able to walk without any aids. The condition of their lower extremities ranged from Brunnstrom's stage 3 to 5. And none had cardio-respiratory dysfunction. Informed consent was obtained from all subjects prior to their participation. The procedure was performed as follows: After all subjects had rested in a sitting position, they were directed to walk indoors at a comfortable speed. All patients were allowed to use their brace or cane or both. The gait distances for 5 min. of all subjects were measured. Heart rates were taken before gait and recovery heart rates were also measured after gait by palpation at the radial arteriy. The recovery heart rate was defined as the total number of heart beats during the 1-1.5 min., 2-2.5 min., and 3-3.5 min. intervals just after gait. GEI values were obtained for all subjects. The GEI was defined as the gait distance for 5 min. / the recovery heart rate × 100. Oxygen uptakes and heart rates during gait were measured with portable equipment in 13 of the hemiplegics and the 11 healthy subjects. The gait distance for 5 min., the recovery heart rate and the GEI were measured twice in 23 of patients within a two weeks period to test for reproducibility. Student's test and Spearman's correlation were used in the statistical analysis. Differences of $p < 0.05$ were judged statistically significant. The following case is described as an example of the use of the GEI : The patient was a 58-year old man who sustained left hemiplegia after a stroke. Under close supervision, he was able to walk with an ankle-foot orthosis and a cane after physical therapy for two months. He was discharged, and the GEI was used to evaluate his physical fitness during follow-up treatment as an outpatient.

Result

1. The 5 min. gait distance of the patients was 135 ± 57 m and that of the control group was 244 ± 40 m. The difference was significant (p< 0.001) (Table 1).
2. The recovery heart rate of the patients was 123±22 and that of the control group was 132±17. There

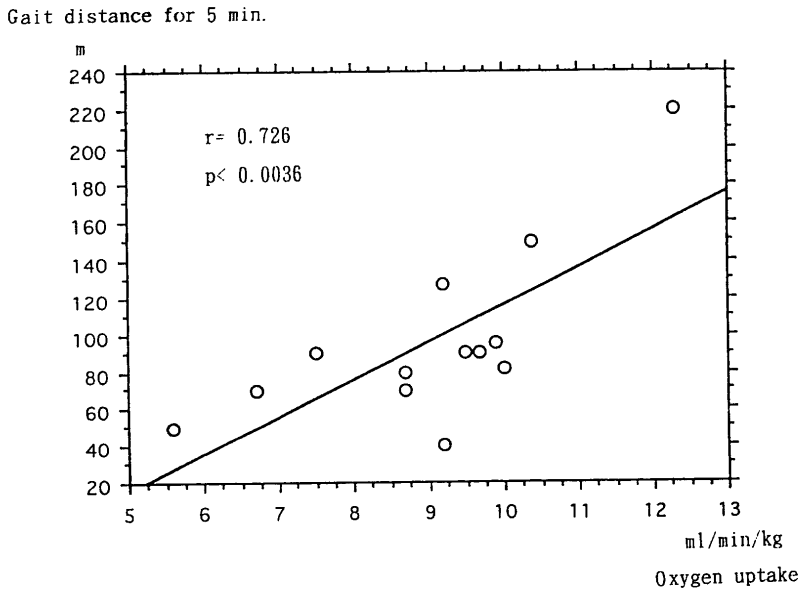

Fig. 1 A significant correlation was found between the gait distance for 5 min. and oxygen uptake in 13 hemiplegics.

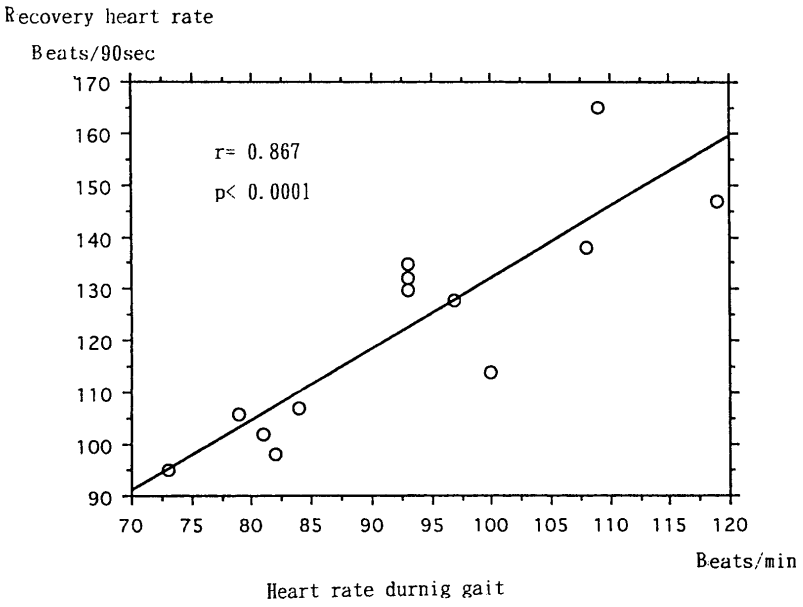

Fig. 2 A significant correlation was found between the recovery heart rate and the heart rate at a steady state during gait in 13 patients.

was no significant difference (Table 1) .

3. The GEI of the patients was 114±52 and that of the control group was 188±36. The difference was significant ($p<0.01$) (Table 1).
4. A significant correlation was found between the gait distance for 5 min. and oxygen uptake ($r = 0.726$, $p < 0.0036$) (Fig 1) and between the recovery heart rate and the heart rate at a steady state during gait ($r = 0.867$, $p < 0.0001$) (Fig 2) . The result was the same for the control group. There was no correlation between the recovery heart rate and the gait distance for 5 min. in either the patients or the control group.
5. No significant differences were found between the first and the second measurements for the heart rate at rest, the gait distance for 5 min., the recovery heart rate and the GEI in the 23 patients who

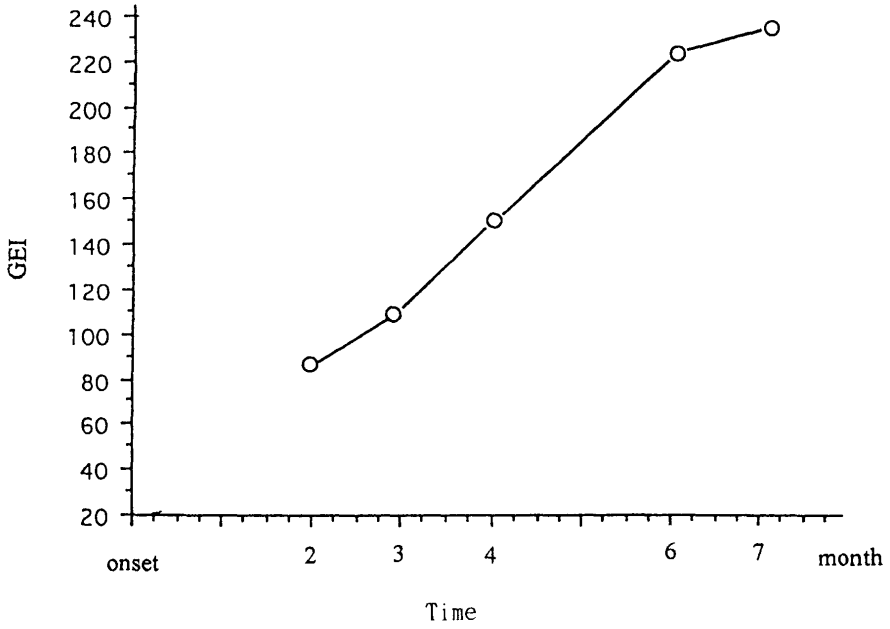

Fig. 3 The process of change in the GEI in one follow up patient is shown.

were measured twice within a two week period.

6. The change in the GEI of one patient who was followed up as an outpatient is shown in Fig 3. The change in his GEI could be easily understood. At discharge, his gait distance for 5 min. was 100m and the recovery heart rate was 113, resulting in a GEI score of 88.5. Five months later, his gait distance for 5 min. was 214 m and the recovery heart rate was 94 for a GEI of 228.

Discussion

A patient's maximal oxygen uptake is commonly used as the parameter of physical fitness, as long as the subject has no motor system dysfunction. If the subject has a motor dysfunction such as hemiplegia, it is very difficult to measure cardio-respiratory system function, which is the core of physical fitness, using the exercise mode. Graded exercise testing, using a treadmill or a bicycle ergometer, is generally carried out to measure physical fitness, but subjects must have good gait abilities and functioning of the lower extremities, since the gait on a treadmill is rather unstable and pedaling the bicycle ergometer is difficult for hemiplegic patients. There are some ergometers, such as bicycle ergometers in the supine position [9] and ergometers for the upper extremities [10][11][12], which take into account the disabilities of hemiplegics. However, with the former type of ergometer, it has been said that the maintenance of cycling speed and the motions of the upper extremities are limited by oxygen utilization in the muscles rather than by the cardio-respiratory oxygen supply. Some investigators have also reported on graded exercise testing methods involving repetition of basic movements. These basic movements, such as flexion-extension of the trunk [3], standing up and sitting down [13], and going up and down stairs, are easier to manage clinically, but measurement of maximal oxygen uptake is considered difficult because of the limits of graded exercise tests. It is also necessary for the patient to wear a mask to collect expired gases for analysis. This procedure is rather troublesome, uncomfortable, and even risky for some patients (Fig 4.). Furthermore, the equipment is so expensive that it is not available in most clinical settings.

What are the reasons for evaluating physical fitness in hemiplegic patients? In the first stage of rehabili-

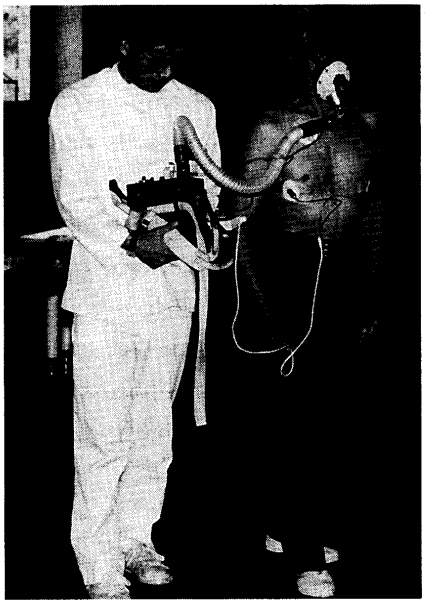

Fig. 4 It is necessary to wear a mask to collect expired gases for analysis. The process is rather troublesome and uncomfortable.

tation in hemiplegic patients, improvements in the activities of daily living (ADL) and gait ability are the primary aims. After these are achieved, the patient is discharged and allowed to return to work or undergo outpatient or community rehabilitation services. In this stage of adjusting to ADL and activities parallel to daily living (APDL), many patients who have achieved independent gait often begin to complain of fatigue and deterioration of physical fitness. In more severely disabled patients, deterioration of physical fitness is not the major problem, rather the deterioration of ADL and APDL is the main problem. Families often complain that patients tend to lie down instead of sitting or walking. The authors think that patients who have achieved independent gait indoors and ADL capability should be distinguished from the severely disabled.

The independent gait and ADL capable group were the focus of this study. In this group, gait endurance greatly influences ADL. Improvement of gait endurance enlarges the range of activities, such as working, walking, shopping, leisure, and sociability and results in improvement of the quality of life (QOL), especially during the follow up period, when the patients' functions plateau. Therefore, in this kind of group, more emphasis should be placed on gait endurance rather than on the response of the cardio-respiratory system in evaluating physical fitness. However, in measuring performance, it is probably easier to measure gait distance for 5 min. rather than gait endurance. Measuring the gait distance for 5 min. should be considered valid, since Inasaka et al [14] reported that gait speed reflected gait endurance. However, the question of the response of the cardio-respiratory system during gait should not be ignored. The measurement of the gait distance for 5 min., i.e., the gait speed, means measurement of the intensity of movement. A faster gait means more activity and a greater response by the cardio-respiratory system. Adjusting the performance to the response of the cardio-respiratory system enhances the validity of the evaluation of physical fitness.

The PCI is defined as the heart rate during gait minus the heart rate at rest /gait speed. The authors utilized the recovery heart rate procedure developed by Brouha [15], because it is not easy to measure the heart rate during gait. As a result, the new "GEI" concept is expressed as the gait distance for 5 min. / the recovery heart rate $\times$ 100. This index follows the method of Kubota et al, who measured the

endurance index using a step test based on the Harvard step test that Brouha developed [13]. Kubota et al measured the endurance index in 42 hemiplegic patients who were able to walk under supervision or independently, and 16 healthy subjects. The GEI is composed of two elements, gait distance for 5 min. and the recovery heart rate. The gait distance for 5 min. is significantly correlated with oxygen uptake during gait and the recovery heart rate showed a significant correlation with the heart rate during gait. There was no significant correlation between the gait distance for 5 min. and the recovery heart rate. This result signifies that the two elements are independent of each other but are correlated with the intensity of exercise and validates the work of Kubota et al in their step test study. The new method is considered to be valid as an evaluation of physical fitness, because the control group showed results similar to the 13 hemiplegic patients. Furthermore, when the measurements were repeated a second time, there were no significant differences between the first and the second results. These findings indicate that the new method is reproducible and reliable.

The authors consider this method to be a useful index when evaluating the physical fitness of hemiplegic patients with rather high gait ability, i.e., beyond the supervision level indoors. Conversely, this method cannot be applied to patients with lower gait abilities. The gait distance for 5 min. in the hemiplegic patients was 61% and the GEI was 56% when compared with healthy elderly subjects. This indicates that the GEI mainly depends on the gait distance for 5 min. or gait speed, i.e. the performance ability, or response of the respiro-circulatory system.

The authors believe this method can also be used to assess the physical fitness of hemiplegic patients whose gait abilities are improving or being maintained at a constant level. The index is very easy to understand so it may also be useful for motivating patients. Our method is based on a concept similar to that of the PCI. The PCI was developed by McGregor and is defined as the heart rate during gait minus the heart rate at rest / the gait speed. Imada et al [7] reported that the PCI of patients was significantly larger than that of healthy subjects, since patients walk more slowly relative to the increase in heart rate. Ohmachi et al [8] studied the influence of walking habits on the PCI of hemiplegic patients. The authors think the PCI is also a convenient and useful index and should be applied more frequently to hemiplegic patients, but that it is also necessary to measure the heart rate during gait. Imada et al measured the heart rate with an electrocardiogram telemeter and Omachi et al used an automatic sphygmomanometer immediately after but not during gait. The present method requires only a watch to use it. Indices, such as $\dot{V}O_2$ max and methods of measuring physical fitness using graded exercise testing with a treadmill or an ergometer, have been utilized mainly in healthy people without motor dysfunctions. However, the concept of physical fitness should be more flexibly applied to subjects with motor dysfunctions such as hemiplegia. The method of measurement must be convenient and economical enough to be available in all clinical settings. The new method fits these qualification and can be useful in certain limited cases.

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