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Reliability and Validity of a New Test for Muscle Power Evaluation of Stroke Patients

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Abstract. [Purpose] The purpose of this study was to establish an optimal load setting method for a 9-second modified-Wingate Anaerobic Test (m-WAnT) and to examine the reliability and validity of the test. [Subjects] The subjects were 28 hemiplegic stroke patients and 18 of them were examined as to the test's validity. [Methods] The m-WAnT was performed twice on two different days to calculate the Mean Power (MP). In order to derive an optimal load setting expression, multiple regression analysis was performed using the optimal load (a value roughly 10% higher than the torque value achieved at the time-point of 6 seconds) as the dependent variable and 6 items as the independent variables. The Five-Repetition Sit-to-Stand Test (FRSST) and Maximum Walking Speed (MWS) were measured and their correlations with were examined the MP. [Results] The ICC (1,1) of the MP of the first and second values of MP was 0.982 (95% CI, 0.961–0.991). The result of multiple regression analysis showed that the unaffected side and affected side LEPT were significantly related and the coefficient of determination (R^2) was 0.812. MP significantly correlated with FRSST and MWS of the 18 subjects. [Conclusion] This study confirmed the reliability and validity of m-WAnT and derived the optimal load setting equation as well.
Key words: Modified-Wingate anaerobic test, Reliability, Validity

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INTRODUCTION

For stroke patients, "physical fitness" is an essential element for independence in their daily lives, and having "physical fitness" can enable them to lead an active life. Miyashita[1)] defined physical fitness as the ability to externally perform muscular activity. While energy is necessary for performing muscular activity to accomplish a task, energy is generated in our body through three kinds of processes, namely the ATP-CP (adenosine triphosphate-creatine phosphate), anaerobic glycolysis and aerobic processes. The state of "having physical fitness" can be thought of as the state in which a certain amount of work can be done, or a certain amount of energy can be exerted within a certain time period. Essentially, although it is deemed advisable to measure the energy that can be exerted during exercise when evaluating physical fitness, it is virtually impossible to measure the chemical reactions within the body over time. Given this fact, it is believed to be the best method to comprehensively detect the mechanical energy exerted by muscular activity due to performed actions, namely muscle power.

While varying reports have been presented thus far regarding the evaluation of physical fitness of stroke patients[2–4)], most of them have focused on isometric muscle strength or aerobic exercise capacity and none have demonstrated any evaluation method from the perspective of muscle power, which is the anaerobic exercise capacity. For this reason, the authors have developed a test method which can be implemented for stroke patients with hemiplegia, with reference to the Wingate Anaerobic Test (WAnT)[5)], a standard method for evaluating anaerobic exercise capacity. WAnT is a 30-second all-out cycling test, which detects changes in mechanical power over a 30-second duration, which is obtained as the product of resistance force generated by a suspended plumb bob and pedal rotational velocity. Because WAnT has an excellent reproducibility and validity, much data has been accumulated[6–10)]; however, only a few reports have described the test being performed by disabled persons[11–14)] and no study has reported its performance by stroke patients. Therefore, we devised a modified-WAnT (m-WAnT) for stroke patients with hemiplegia using a recumbent ergometer in a preceding study[15)]. In that study, we could confirmed the feasibility of the test for stroke patients, using a 9-second protocol, and the reproducibility of the obtained power data. Nevertheless, a review of the optimal load setting method for obtaining more stable data was required and, in addition, validation of the m-WAnT.

Based on the above considerations, in this study we

Table 1. Characteristics of all the subjects and those participation in the validity investigation

	All subjects (n=28)	Subjects of the validity investigation (n=18)
Sex (Male / Female)	19/9	14/4
Age (years)	57.4 ± 9.2	56.2 ± 9.2
Weight (kg)	62.5 ± 11.5	61.3 ± 11.1
Period of onset (days) (Range)	83.2 ± 53.0 (18–224)	83.2 ± 60.3 (18–224)
Disease Cerebral infarct	16	11
Cerebral hemorrhage	11	6
Subarachnoid hemorrhage	1	1
Side of hemiparesis (Right/Left)	16/12	12/6
L/E BRS 3	5	4
4	5	4
5	13	7
6	5	3
Leg extension peak torque (Nm)		
Unaffected side	72.7 ± 27.9	–
Affected side	49.5 ± 28.2	–

Mean ± standard deviation (SD), L/E: Lower Extremity, BRS: Brunnstrom Recovery Stage.

attempted to establish an optimal load setting method for a 9-second m-WAnT and to examine the reliability of the power data and its validity by considering the relationship between the obtained power data and short-term exercise performance.

SUBJECTS AND METHODS

Subjects

The subjects of this study were 28 stroke patients with hemiplegia, 19 males and 9 females with a mean age of 57.4 ± 9.2 years, who were hospitalized in either of two hospitals. The test validity was examined with 18 of the 28 patients, 14 males and 4 females with a mean age of 56.2 ± 9.2 years and a mean body weight of 61.3 ± 11.1 kg. The attributes of these subjects are shown in Table 1. Convalescing patients with a medically stable state who suffered hemiplegia at the first onset of cerebrovascular disease were included in this study and those with severe cardiorespiratory disease or lower extremity orthopedic disease were excluded. This study was performed with the approval of the Ethics Committee of Hirosaki University School of Medicine and only after obtaining the subjects' consent after giving each of them an explanation of the purpose and details of this study.

Methods

For the m-WAnT, the StrengthErgo240 (SE240, Mitsubishi Electric Engineering Company, Ltd., Tokyo, Japan) recumbent ergometer was employed. In the pedaling position, each subject grasped the arms equipped on the right and left sides of the seat to support their upper extremities. The angle of the backrest was set at 110 degrees relative to the seat face, and the trunk was secured with a safety-belt. The position of the seat was set so that knee flexion was 30 degrees when the lower extremity was in the maximum extended position. A cycle with a crank length of 170 mm was used and a crank with an external rotation preventing mechanism was used for subjects at risk of riding instability, which can be caused by inadequate control of the hip joint. Based on previous studies[15], the Leg Extension Peak Torque (LEPT) was determined from 5 rotational pedaling motions at a rate of 50 rotations/minute in an isokinetic mode and the load for the m-WAnT was set at 15% LEPT on the unaffected side obtained in this manner. Subsequently, following a 3-minute warm-up with a load of 10 W, a 9-second test was performed with the 15% LEPT load (with a ramping-up load for the period from 0 to 6 seconds after the start of exercise and with a constant load from 6 to 9 seconds after the start of exercise). The m-WAnT was performed twice on two different days to calculate the Mean Power (MP) for the period from 6 to 9 seconds after the start of exercise (for 3 seconds), with the constant load.

To examine the validity, the Five-Repetition Sit-to-Stand Test (FRSST) and Maximum Walking Speed (MWS) were measured. For the FTSST, a therapeutic platform without a backrest or armrest and with a height of 45 cm was used; the seat is difficult to move if pushed when standing up. The legs were positioned at the start so that a space about the size of a fist (some 10 cm) was created in the –popliteal region with the feet shoulder-width apart in a sitting position. Regarding the upper extremities, subjects folded their arms or held their affected forearm with their unaffected upper extremity. For FRSST, the subjects repeatedly stood from a sitting position at the start signal and sat down as quickly as possible five times and the time their buttocks made contact with the seat was defined as the end. The measurement was performed three times and the fastest value was used in the analysis. For MWS, the time required to walk a 10-m path with 3-m runways at the start and end of the path as fast as possible was measured. Subjects were allowed to use their orthosis or a cane that they usually used. The measurement was performed three times and the fastest value was used in the analysis.

Table 2. Intraclass correlation coefficient ICC (1,1) of mean power of the first and second measurements of the hemiplegic stroke patients (n=28)

	m-WAnT			
	1st	2nd	ICC(1,1)	95%CI
MP (W)	190.8 ± 130.2	197.8 ± 133.0	0.982	(0.961–0.991)

Mean ± standard deviation (SD), m-WAnT: modified-Wingate Anaerobic Test, 1st: First measurement, 2nd: Second measurement, ICC: Intraclass correlation coefficient, CI: confidence interval, MP: Mean Power.

Table 3. Stepwise multiple linear regression analysis to determine the factors related to optimal load (n=18)

Variable	Partial regression coefficient	Standardized partial regression coefficient	P value	Partial correlation coefficient	VIF
(constant)	–7.97		0.018		
Unaffected LEPT	0.273	0.604	0.001	0.88	3.057
Affected LEPT	0.151	0.336	0.036	0.832	3.057

ANOVA, $p<0.01$, R=0.901, R^2=0.812. VIF: Variance Inflation Factor, LEPT: Leg Extension Peak Torque.

Table 4. Correlation coefficients between MP, FRSST, and MWS of the subjects of the validity investigation (n=18)

Variable	Mean ± SD	Correlation coefficient with MP
MP (W)	237.2 ± 148.8	–
FRSST (seconds)	6.62 ± 1.67	–0.549*
MWS (seconds)	8.79 ± 6.82	–0.490*

Mean ± standard deviation (SD), *: $p<0.05$, by Spearman's rank correlation coefficients. MP: Mean Power, FRSST: Five-Repetition Sit-to-Stand Test, MWS: Maximum Walking Speed.

While the load was set based on the LEPT value obtained for the unaffected leg of subjects, it was deemed necessary to include other factors as conditions in order to set a more appropriate load. Furthermore, it was shown in a preliminary experiment that a stable load can be achieved by setting the constant load from 6 to 9 seconds after the start of exercise at a value roughly 10% higher than the torque value achieved at 6 seconds after the start of exercise. Based on this finding, we calculated the torque value at 6 seconds after the start of exercise in the m-WAnT, and set the optimal load as a torque value 10% highest than the highest value of the first and second results.

The reliability of the mean power of the first and second m-WAnT was verified using the intraclass correlation coefficient, ICC (1,1). In order to derive the optimal load setting expression for the 9-second m-WAnT using the SE240, multiple regression analysis with a stepwise method was performed using optimal load as the dependent variable and sex, age, body weight, lower extremity BRS, affected side LEPT and unaffected side LEPT as the independent variables. The validity of m-WAnT was examined for the highest MP of the first and second tests and the results of FRSST and MWS using Spearman's rank correlation coefficient. SPSS 16.0 statistic software was used for statistical processing and statistical significance levels of 0.05 and 0.01 were used.

RESULTS

A 9-second m-WAnT was feasible for all subjects and no subject complained of having a poor physical condition immediately after the test. The results of m-WAnT showed 190.8 ± 130.2 for the first trial and 197.8 ± 133.0 for the second. The ICC (1,1) of the MP for the first and second values was 0.982 (95% CI, 0.961–0.991) (Table 2).

The result of multiple regression analysis using optimal load as the dependent variable (Table 3) showed that the unaffected side LEPT and affected side LEPT were significantly related ($p<0.01$) and the coefficient of determination (R^2) was 0.812. Moreover, the optimal load setting expression was as follows:

Optimal load = 0.273 × Unaffected side LEPT + 0.151 × Affected side LEPT–7.970 (constant)

The MP of the 18 subjects examined for validity was 237.2 ± 148.8, the FRSST was 6.62 ± 1.67, and MWS was 8.79 ± 6.82. Spearman's rank correlation coefficients between MP and FRSST and between MP and MWS were –0.549 ($p<0.05$) and –0.490 ($p<0.05$), respectively, showing significant negative correlation (Table 4).

DISCUSSION

For WAnT, optimal load setting criteria varies depending on the ergometer[16–18] and it is known that, in the case of a healthy subject, the maximum anaerobic power of the subject can be derived by setting the optimal load based on the subject's body weight, sex and activity level. However, in a preliminary experiment it was determined to be difficult to set the optimal load using only a subject's body weight for patients with hemiplegia. In previous reports on WAnT performed by the disabled, Van Mil et al.[19] proposed that the optimal load for youths with cerebral palsy can be predicted by primarily determining the optimal force through a force-velocity test and then performing WAnT with 65% of that force. Therefore, we calculated the unaffected side LEPT of stroke patients with hemiplegia referring to the method used by Van Mil et al. and set the load as 25% of the obtained torque in the preliminary experiment for this study. Yuri et al.[20] reported that the anaerobic threshold when the SE240 is used was roughly 12 % of the maximum torque, and we tried to perform the test with 25% or nearly double that value. However, 25% is an excessively high load for stroke patients with hemiplegia, and since a preceding study[15] performed the test at 15% of the unaffected side LEPT we adopted this value. The procedure to set loads that suit a hemiplegic subject's abilities was then considered based on the obtained results. The result of multiple regression analysis showed that only the unaffected side LEPT was significantly related and the coefficient of determination (R^2) was 0.723. This study performed multiple regression analysis with a stepwise method, with 28 stroke patients with hemiplegia as subjects, using optimal load as the dependent variable and six parameters as independent variables the same as in a preceding study. The variables that were significantly related were the affected side LEPT and unaffected side LEPT. In this study, the load setting equation for m-WAnT, which included the function of the lower extremities of stroke patients with hemiplegia, could be derived because the affected side LEPT and unaffected side LEPT were significantly related and the coefficient of determination (R^2) at 0.812 was higher than that obtained in a preceding study. The ICC (1,1) of the power data obtained in the 9-second m-WAnT that was performed in this study was as high as 0.982, which reconfirmed the reliability of the test method using the SE240. Furthermore, the SE240 allows stable pedaling even by persons with decreased motor function, such as stroke patients with hemiplegia, and is a suitable piece of equipment for measuring lower extremity muscle power.

Since m-WAnT aims to measure lower extremity muscle power in an anaerobic exercise in a brief all-out pedaling motion, we examined its validity from the viewpoint of its relationship with tasks that can be performed within a short period of time. Accordingly, we focused on sit-to-stand and walking as motion tasks that are performed on a regular basis and require no special technique or apparatus. Though tests of sit-to-stand motion have been performed in different ways, most studies have[21–23] focused on the association with lower extremity muscle strength exerted in monoarticular movements like isometric knee extension muscle strength; however, no previous has addresed lower extremity muscle power from the viewpoint of it being exerted by compound articular movement. It is important to exert power by sustaining muscular activity for a certain period of time in order to judge whether or not ADL movement can be performed. Given this brief all-out FRSST is an appropriate method for testing lower extremity muscle power. Moreover, Saito et al.[24] reported that they performed an agility test in which subjects performed 50 repetitions of maximum stepping motion in the standing position. The period from the contact of one foot with the floor to the contact of the other foot with the floor was defined as 1 step, and there was a correlation between the mean duration of the agility test performance time and MWS. This result suggests that MWS is a brief all-out performance assessment including a factor of agility and requiring lower extremity muscle power. The fact that there was a correlation between FRSST and MP and between MWS and MP in this study is one possible basis for indicating the validity of m-WAnT in evaluating the anaerobic exercise capacity of hemiplegic patients. However, there is a report that the aerobic energy contribution is 28%–13% when assuming a mechanical efficiency of 22% in original WAnT[6]. Therefore, it should be assumed that the m-WAnT and each performance test of maximal exercise in this study are also receiving aerobic energy supply.

This study confirmed the reliability and validity of m-WAnT and derived the optimal load setting equation as well. However, the SE240, a recumbent ergometer, is required for m-WAnT, so the facilities which do not have this device cannot perform the test. FRSST is easily performed in the clinical practice. In addition, this study was performed by stroke patients with hemiplegia, which first and foremost requires the consideration of risk management. For this reason, it is ethically difficult to push subjects too hard as is the case with studies of sports athletes[25,26] and it is a limitation of this study. However, this study has clinical significance in that it tried to evaluate parameters other than the aerobic exercise capacity in the physical fitness evaluation of stroke patients with hemiplegia. It will be necessary to accumulate data by using the newly developed m-WAnT and to examine the relationship to other performance assessments or ADL in the future. Furthermore, we'd like to clarify the clinical significance of muscle power by performing longitudinal research.

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