Original

Influence of Muscle Strength of the Hemiparetic Lower Limb on Independent Stair Ascent and Descent with the Use of an Ankle Foot Orthosis in Stroke Patients

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(Received: November 20, 2017)

Abstract

The purpose of the present study was to determine the level of the muscle strength of the hemiparetic lower limb that should be achieved for independence in stair ascent and descent in stroke patients using an ankle foot orthosis.

Thirty-nine stroke patients without higher cortical function disorders were involved. Muscle strength of both the hemiparetic and non- hemiparetic lower limbs, Brunnstrom recovery stage of the lower limbs, deep sensation, and stair ascent and descent performance were the variables studied.

The results of the logistic regression analysis showed that muscle strength of the hemiparetic lower limb was a significant predictor of the independent group ($p < 0.05$). A muscle strength 0.19 kgf/kg on the hemiparetic lower limb gave a clear cut-off value, with a sensitivity of 86.7%, a false-positive rate (1−specificity) of 20.8%, a positive predictive value of 82.1%, and a negative predictive value of 90.5% Therefore, The present study showed that independence in stair ascent and descent in stroke patients using an ankle foot orthosis required a muscle strength of the hemiparetic lower limb above 0.19 kgf/kg.

(JJOMT, 66: 283—288, 2018)

—Key words—
muscle strength, stair ascent and descent, stroke

Introduction

Stair ascent and descent is an important activity of daily living (ADL) involved in transfer and walking. However, Paolucci indicated that only 5 to 25% of stroke patients have independence in stair ascent and descent at their discharge home following early rehabilitation[1]. Therefore, stair ascent and descent is one of the high difficulty motions in ADL.

An ankle-foot orthosis (AFO) is recommended to compensate for the effects of impairments to ambulation and can support rehabilitation after stroke. AFOs have significant effects on long-term hemiparetic patients with respect to lateral weight shifting and weight bearing through their hemiparetic side[2]. An AFO can provide lateral stability to the ankle in the stance phase and facilitate toe clearance in the swing phase[3]. Several studies have shown that an AFO improves walking speed[4)~6], stride length[7], walking efficiency[4], and gait pattern[8]. Even in stair ascent and descent, there is a possibility that an AFO has a positive effect. Stair ascent and descent performance is dependent on adequate lower limb strength[9,10] and power[11] in older adults. The muscle strength of the lower limb in persons with stroke has been shown to relate to the performance of several functional tasks, such as transfer[12], walking[13~15], and stair ascent and descent[16]. We inferred that a certain level of muscle strength of the lower limb is necessary for independence in stair ascent and descent in stroke patients using an AFO. Determining the level of physical function required for the hemiparetic lower limb for independence in stair ascent and descent would be useful for assessing the cause of disorders and for selecting therapeutic exercises.

The purpose of the present study was to determine the level of the muscle strength of the hemiparetic lower limb that should be achieved for independence in stair ascent and descent in stroke patients using an AFO.

Methods

Participants

Thirty-nine stroke patients without higher cortical function disorders were involved. All patients used an AFO. Informed consent was obtained from all patients. The average ± standard deviation (SD) age at the time of study was 65.9 ± 8.3 years. The average time (± SD) from stroke onset was 112.2 ± 68.8 days. Sixteen subjects were men and 23 women. Twenty-three patients were right hemiparetics, and 16 were left hemiparetics. Of the participants, 36 patients wore a plastic shoe horn brace, and three patients wore a double upright AFO with an adjustable ankle joint.

Procedure

Muscle strength of both the hemiparetic and non- hemiparetic lower limbs, Brunnstrom recovery stage of the lower limbs, deep sensation, and stair ascent and descent performance were the variables studied.

We did the measurements of stair ascent and descent performance in the hospital using 12 steps of riser 18 cm and run 30 cm because the stairs of public accommodation are required by Japanese Building Standards Law to have a riser of less than 18 cm and a run of 26 cm or more. For measurement of stair ascent and descent performance, the patients who could ascend and descend the stairs in the hospital independently and safely were categorized as the independent group, and those who needed observation or any assistance by a staff member were the dependent group.

Brunnstrom recovery stages showed the degree of motor function recovery. The level of motor paralysis was evaluated by the measurement of Brunnstrom's six recovery stages[17]. The lowest stage, flaccid stage and no voluntary movement, was defined as stage I, and the highest stage, isolated joint movement and not normal movement, was defined as stage VI.

To measure the muscle strength of the lower limb, quadriceps muscle strength was measured using a hand-held dynamometer (Anima, μ-Tas MT-01). The patients were asked to sit upright on a mat platform with both upper extremities crossed in front of the trunk without back support and keeping the knees flexed at 90 degrees. The dynamometer was attached to the front of the distal lower leg. The patients were then asked to make a maximum isometric contraction of the quadriceps for 5 s, twice, with a time interval of more than 30 s. The stronger value (kgf) of the two was divided by the body weight. This value (kgf/kg) was defined as the muscle strength of the lower limb.

Joint sensation was used as a measure of deep sensation. First, the patient's hip joint, knee joint, and ankle were moved passively, and then the patient was asked to imitate the movements on the non-paralyzed side. Each joint was evaluated five times: a difference of up to 10 degrees in the joints was considered normal, whereas at least one difference of $\geq$ 11 degrees was considered abnormal.

The differences between the independent group and the dependent group were compared using the χ^2 test and the Mann-Whitney U test. A logistic regression analysis was used to identify the optimal predictor variable in the independent group. The usefulness of the physical function for predicting the independence in stair ascent and descent was studied using a receiver operating characteristic (ROC) curve, and the cut-off value necessary for independence in stair ascent and descent was determined. Predictability was evaluated using the sensitivity, false-positive rate (1−specificity), predictive accuracy, and the positive predictive value. Also, the Spearman rank-order correlation was used to determine correlations between the muscle strength of the hemiparetic limb and the Brunnstrom recovery stage of the lower limbs. Statistical analysis was conducted using SPSS Version 22.0 (IBM, Chicago, IL, USA). Confidence levels in all analyses were $p < 0.05$.

Table 1 Comparison of valuables between the independent and dependent groups (n=39)

Variable	Independent group (n=15)	Dependent group (n=24)	p value
Age (y) [a)]	67.9 (9.8)	67.5 (9.4)	0.898
Muscle strength of the hemiparetic limb (kgf/kg) [a)]	0.26 (0.09)	0.13 (0.09)	p<0.001
Muscle strength of the non-hemiparetic limb (kgf/kg) [a)]	0.46 (0.12)	0.43 (0.16)	.521
Brunnstrom recovery stage of lower limbs (n) [b)]	III: 4, IV: 5, V: 2, VI: 4	III: 12, IV: 8, V: 3, IV: 1	.081
Deep sensation (normal/abnormal) (n) [b)]	4/11	6/18	.007

a) mean (SD), b) proportion

Table 2 Predictors of stair ascent and descent ability (n=39)

Variable	Odds Ratio (95%CI)	p value
Age (y)	0.999 (0.913-1.092)	.974
Muscle strength of the hemiparetic limb (kgf/kg)	1.162 (1.034-1.307)	.012
Deep sensation (normal/abnormal) (n)	0.186 (0.034-1.037)	.186

CI: confidence interval.

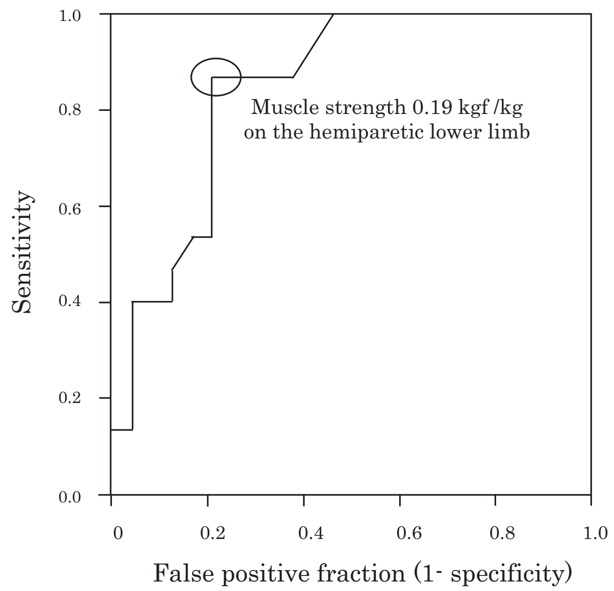

Fig. 1 Receiver operating characteristic curve for prediction of independence stair ascent and descent
NOTE. The areas under the curve is 0.951, with SE 0.016 and 95% Confidence Interval 0.919–0.983.

Results

Of the 39 patients, 15 were categorized in the independent group and 24 in the dependent group.

The results of the univariate analysis are shown in Table 1. Muscle strength of the hemiparetic lower limb and deep sensation were significantly different between the two groups ($p < 0.05$).

The results of the logistic regression analysis showed that muscle strength of the hemiparetic lower limb was a significant predictor of the independent group ($p < 0.05$) (Table 2).

The results of the ROC curve analysis indicated that muscle strength of the hemiparetic lower limb was most strongly related to stair ascent and descent performance. The area under the curve was 0.846, with SE 0.062 and 95% confidence interval 0.725–0.967. A muscle strength 0.19 kgf/kg on the hemiparetic lower limb gave a clear cut-off value, with a sensitivity of 86.7%, a false-positive rate (1−specificity) of 20.8%, a positive predictive value of 82.1%, and a negative predictive value of 90.5% (Fig. 1).

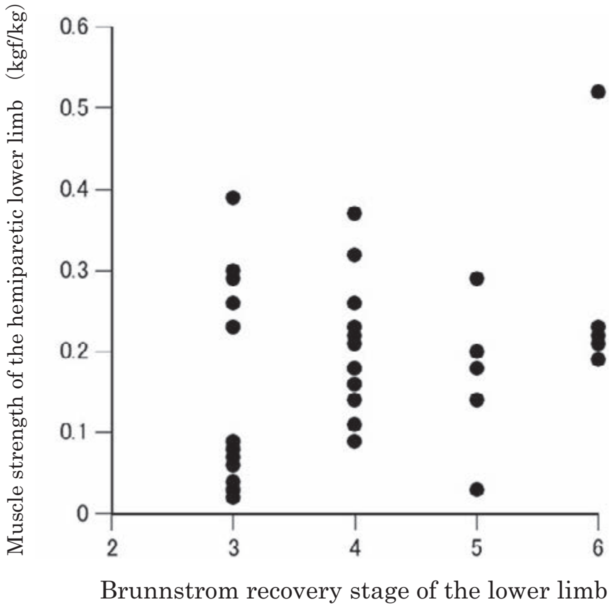

Fig. 2 Relationship between muscle strength of the hemiparetic lower limb and Brunnstrom recovery stage of the lower limb

There was no significant correlation between muscle strength of the hemiparetic lower limb and Brunnstrom recovery stage of the lower limb. For the Brunnstrom recovery stage of the lower limb III, muscle strength of the hemiparetic lower limb was 2–39%, IV was 9–37%, V was 3–29%, and VI was 19–52% (Fig. 2).

Discussion

The purpose of the present study was to determine the level of muscle strength of the hemiparetic lower limb that should be achieved for independence in stair ascent and descent in stroke patients using an AFO. Muscle strength of the hemiparetic lower limb was the most useful predictor of an independent in stair ascent and descent with the use of an AFO in stroke patients.

Two studies found significant correlations between muscle strength of the hemiparetic lower limb and stair ascent and descent performance[16][18]. Flansbjer demonstrated that the strength of the non-hemiparetic lower limb did not have a significant correlation with stair climbing speed[18]. The univariate analysis of the present study showed that muscle strength of the hemiparetic lower limb and deep sensation were significantly different between the independent group and the dependent group. The logistic regression analysis showed that only the muscle strength of the hemiparetic lower limb was a critical factor influencing the stair ascent and descent performance. Therefore, although multiple factors influenced the independence in stair ascent and descent in stroke patients using an AFO, the muscle strength of the hemiparetic lower limb was the most useful predictor.

The present study showed that independence in stair ascent and descent in stroke patients using an AFO required a muscle strength of the hemiparetic lower limb above 0.19 kgf/kg. This cut-off value had a high sensitivity, predictive accuracy, and positive predictive value. Our study suggests that muscle strength 0.19 kgf/kg on the hemiplegic lower limb would be a fair target for rehabilitation.

As a result of the present study, there was no significant correlation between motor paralysis and muscle strength of the hemiparetic lower limb. The muscle strength in each Brunnstrom recovery stage varied widely, and patients with a high Brunnstrom recovery stage, such as stage V and VI, did not always have a high muscle strength of the hemiparetic lower limb. Therefore, measurement for the function of the hemiparetic lower limb requires not only motor paralysis but also measurement of muscle strength of the hemiparetic lower limb.

There were two limitations to this study. First, we set the height of the stairs to 18 cm. However, at greater heights, higher body functions are required, so the cutoff value shown in the results of this study may be different. Second, the study excluded patients with higher cortical function disorders, but the results may differ if these patients are included. Further research is needed to determine these effects.

Acknowledgements

We would like to thank all of the patients who have participated for their cooperation.

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短下肢装具を装着した脳卒中患者における階段昇降自立に対する麻痺側下肢筋力の影響

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—キーワード—
筋力，階段昇降，脳卒中

短下肢装具を装着した脳卒中患者における階段昇降自立に必要な麻痺側下肢筋力値を検討した．

対象は，高次脳機能障害を有していない39名の脳卒中患者とした．麻痺側・非麻痺側下肢筋力，下肢 Brunnstrom recovery stage，深部感覚障害，階段昇降能力を調査・測定した．ロジスティック回帰分析の結果，麻痺側下肢筋力のみ階段昇降自立群に有意差を認めた（$p<0.05$）．麻痺側下肢筋力0.19kgf/kgをカットオフ値とした場合には，感度86.7%，偽陽性率（1-特異性）20.8%，陽性的中率82.1%，陰性的中率90.5%を示した．これらのことから，短下肢装具を装着した脳卒中患者における階段昇降自立には，麻痺側下肢筋力0.19kgf/kgが必要であることが示唆された．

利益相反：利益相反基準に該当無し

（日職災医誌，66：283―288，2018）