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SHORT COMMUNICATION

RELATIONSHIP BETWEEN LOWER LIMB MUSCLE STRENGTH AND 6-MINUTE WALK TEST PERFORMANCE IN STROKE PATIENTS

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Objective: **The aim of this study was to determine if lower limb muscle strength and/or spasticity are related to performance in the 6-min walk test (6MWT) in stroke patients.**
Methods: **A total of 24 patients (12 males and 12 females) participated in the study. Muscle strength (Medical Research Council (MRC) scale) and spasticity (modified Ashworth scale) were assessed prior to the 6MWT. Heart rate was recorded at rest and during the 6MWT. Subjects were divided into two groups: (*i*) those with a high MRC sum score, and (*ii*) those with a low MRC sum score. The relationship between the 6MWT distance and the other parameters was analysed using a Spearman's rank correlation coefficient.**
Results: **There was a significant and positive relationship between 6MWT distance and lower limb muscle strength (*p*=0.001), whereas no significant correlations were found between the 6MWT distance and spasticity, resting heart rate and heart rate during the 6MWT.**
Conclusion: **The 6MWT distance may be a good indicator of lower limb muscle strength, and lower limb strengthening may improve gait capacity in stroke patients.**

Key words: motor impairment; gait; spasticity; heart rate.

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INTRODUCTION

The 6-min walk test (6MWT) (1) is derived from the Cooper 12-min run test (2) and is designed to evaluate the exercise and cardiorespiratory capacity of patients with cardiac and respiratory disease (3, 4). A review of the validity data supporting functional exercise tests has shown the 6MWT to be the most extensively researched and established test for use in clinical or research contexts in the cardiorespiratory domain (5). The 6MWT is easy to administer, better tolerated, and more accurately reflects activities of daily living than other functional gait assessments.

After stroke, between 52% and 85% of patients re-gain the capacity to walk; however, their gait usually remains different from that of healthy subjects (6, 7). The 6MWT is routinely used to assess the functional walking ability of stroke patients for either clinical or research purposes. However, the relationship between the 6MWT and aerobic fitness in the stroke population may be confounded by limitations in walking capacity related to alterations in neuromotor control. For example, 6 months after stroke, 50% of patients still have impaired muscle function (8). Danielsson et al. (9) showed that the 6MWT distance covered by stroke patients correlates with the Fugl-Meyer score, which is an evaluation of sensorimotor impairment. Impairment of function may result from a combination of spasticity and weakness in the same or antagonist muscle groups. Ordinal scales are frequently used in clinical practice to grade spasticity (modified Ashworth scale) (10) and strength (Medical Research Council (MRC) scale). The validity and reliability of the MRC for the evaluation of muscle strength has been established (11). Several previous studies have reported significant correlations between gait velocity and lower limb muscle strength (12, 13), but no study has examined the relationship between lower limb muscle strength and performance in the 6MWT.

Within this context, the aim of this study was to evaluate the relationship between lower limb muscle strength and/or spasticity and performance in the 6MWT in stroke patients. Our hypothesis was that 6MWT performance would correlate strongly with lower limb muscle strength.

METHODS

Subjects

A total of 24 patients (12 males and 12 females, 18 ischaemic and 6 haemorrhagic, stroke duration 16 months (standard deviation (SD) 8)) were included in this study (age: 53.3 years (SD 13.7); height: 171.6 cm (SD 9.0), mass: 73.4 kg (SD 12.3); Table I). Inclusion criteria were: (*i*) history of a single stroke at least 6 months previously; (*ii*) independent gait (with or without assistive devices); (*iii*) medically stable (i.e. no uncontrolled hypertension, arrhythmia, or unstable cardiovascular status); (*iv*) no previous myocardial infarction; and (*v*) no significant musculo-skeletal problems relating to conditions other than stroke. The study was approved by the local ethics committee and all subjects provided written informed consent prior to participation in any study-specific procedures.

Experimental procedure

Firstly, a heart rate (HR) monitor (Polar S625X, Polar Elektro Oy, Kempele, Finland) with a storage function was attached to the patient using a chest strap, and the resting HR was recorded while the patient sat in silence for 10 min. The mean of the HR measured for the last 5 min was used as the baseline value (resting HR).

Next, muscle strength of the major muscles of the paretic lower limb was evaluated using the MRC scale. The MRC scale was initially devised for use in patients with peripheral nerve injuries, but has been validated in stroke patients and is frequently used in clinical practice on this population (11–14). The MRC is an ordinal scale that quantifies muscle weakness (range: 0: absence of movement to 5: muscle contracts normally against full resistance) in isolated muscles or muscle groups (11). Five muscle groups were tested: (*i*) hip flexors, (*ii*) knee extensors, (*iii*) knee flexors, (*iv*) ankle plantar flexors, and (*v*) ankle dorsi flexors. Each measurement was carried out 3 times by the same therapist. MRC scores were averaged in order to obtain a mean score for each muscle group and then summed in order to obtain a total MRC score (MRC sum) for the limb (13). Spasticity was assessed using the Modified Ashworth Scale (MAS) (10) in 3 muscle groups: quadriceps, hamstrings and triceps surae. MAS scores were added together to give a total MAS score (MAS sum) (15). This method of summing of the MRC and MAS scores has been validated previously and is widely used in stroke patients (15–17).

Finally, each subject was instructed to walk as far as possible in 6 min (6MWT distance), at their own speed (4). Subjects walked lengths of a 30-m walking track marked by a cone at each end, which they were instructed to walk around. HR was recorded simultaneously. The Physiological Cost Index (PCI, in beats/min (bpm)) was estimated by dividing the difference between walking (6MWT HR) and resting HR (rest HR) by the walking velocity in m/min (9). To ensure a steady state, the mean of the last 3 min of the 6MWT was used as the walking HR value. Finally, each subject was asked to rate perceived exertion (RPE) on the Borg scale (18) at the end of the test, and the distance covered was estimated to the nearest metre.

Statistical analysis

Subjects were divided into two groups: (*i*) 12 subjects with an MRC sum lower than the median (MRC sum median = 14.5) (LMRC); and (*ii*) 12 subjects with an MRC sum higher than the median (HMRC). All statistical calculations were performed with Statistica 7 software. Means, SDs, range and standard errors were calculated for each parameter for the total population and for each group. Medians and modes were also calculated for the ordinal scales (MRC sum and MAS sum). A multiple linear regression analysis was carried out to identify the variables that were most highly correlated with the 6MWT distance. A stepwise method with variables entered in the model at a significance level of $p < 0.01$ was used. Because the data did not appear to follow a normal distribution, a Spearman's rank correlation coefficient (Rs) was used to evaluate the relationship between the 6MWT distance and the other parameters evaluated. The Rs values were interpreted according to Domholdt's recommendations (19). Differences between LMRC and HMRC groups were determined using a Mann-Whitney test. $p < 0.05$ was regarded as statistically significant.

RESULTS

Anthropometric characteristics (height, weight) and age were not significantly different between the two groups (LMRC and HRMC). Mean 6MWT distance of the total sample was 273.8 m (SD 173.4 m). Median MRC sum of the total sample was 14.5 (mode: 7) and median MAS sum was 3 (mode: 0). Both the distance walked during the 6MWT and the MRC sum were significantly lower in the LMRC group than in the HMRC group (respectively, $p = 0.003$ and $p = 0.0001$, Table I). Mean resting HR of the total sample was 72.29 bpm (SD 11.11 bpm) and mean 6MWT HR was 106.21 bpm (SD 21.41 bpm). The PCI of the HMRC group was significantly lower than that of the LMRC group ($p = 0.008$). There were no significant differences between the two groups for MAS sum, resting HR, 6MWT HR and RPE.

Table I. *Age, anthropometric characteristics (height, weight), total score on the Medical Research Council (MRC) scale, spasticity (Modified Ashworth Scale (MAS)), 6-min walk test distance (6MWT distance), heart rate (HR) at rest and during the 6MWT, Physiological Cost Index (PCI) and rating of the perceived exertion (RPE) on the Borg scale for the total population, the LMRC group and the HMRC group*

	Total ($n = 24$) Mean (SD)	LMRC ($n = 12$) Mean (SD)	HRMC ($n = 12$) Mean (SD)
Age, years	53.38 (13.71)	51.50 (10.54)	55.25 (16.55)
Height, cm	171.63 (9.01)	173.83 (6.22)	169.42 (10.97)
Weight, kg	73.42 (12.39)	73.50 (14.98)	73.33 (9.83)
MRC sum	13.52 (6.87)	8.00 (2.17)	20.00 (3.97)**
MAS sum	3.35 (2.47)	4.17 (2.37)	2.25 (2.26)
6MWT distance, m	273.8 (173.4)	163.3 (101.6)	384.4 (160.8)*
Resting HR, bpm	72.29 (11.11)	70.33 (11.44)	74.25 (10.90)
6MWT HR, bpm	106.21 (21.41)	103.50 (16.53)	108.92 (25.86)
PCI, bpm	1.11 (1.09)	1.74 (1.26)	0.55 (0.31)*
RPE	11.38 (1.88)	11.50 (1.31)	11.25 (2.38)

*$p < 0.01$ **$p < 0.001$.
LMRC: 12 subjects with an MRC sum lower than the median (MRC sum median = 14.5); HMRC: 12 subjects with an MRC sum higher than the median. SD: standard deviation.

The variable selected in the first stage of the stepwise multiple regression was the MRC sum. This variable explained 64% of the variance of the 6MWT distance. The equation for predictive factors of 6MWT distance was as follows:

6MWT distance = –11.4 + 20.37 MRC sum

Spearman's rank correlation coefficients showed a strong, significant and positive relationship between the 6MWT distance and the MRC sum ($r = 0.79$, $p = 0.001$), and a significant, moderately strong negative relationship between the 6MWT distance and the PCI ($r = –0.54$, $p = 0.006$, Table II). No significant correlation was found between the 6MWT distance and spasticity (MAS sum), resting HR, 6MWT HR and RPE. Finally, a moderately strong, significant, negative correlation was found between the MRC sum and the PCI ($r = –0.62$, $p = 0.001$).

Table II. *Spearman's rank correlation coefficients between the 6-min walk test (6MWT) distance and the other parameters: age, anthropometric characteristics (height, weight), total score on the Medical Research Council (MRC) scale, spasticity Modified Ashworth Scale (MAS), 6MWT distance, heart rate (HR) at rest and during the 6MWT (6MWT HR), physiological cost index (PCI), and rating of the perceived exertion (RPE)*

	Spearman's *r*	*p*
Age	–0.12	0.566
Height	–0.19	0.383
Weight	0.02	0.942
MRC sum	0.79	0.001
MAS sum	–0.39	0.058
Rest HR	0.02	0.929
6MWT HR	0.27	0.200
PCI	–0.54	0.006
RPE	0.28	0.185

DISCUSSION

The aim of this study was to determine, in stroke patients, whether or not lower limb muscle strength and/or spasticity was related to 6MWT performance. The results of this study confirmed our hypothesis, since 6MWT performance was significantly correlated with the MRC sum-score and because the 6MWT HR and the RPE were not significantly different between the two groups (LMRC and HRMC).

The mean distance covered during the 6MWT (range 264–301 m) (20–23), the resting HR, the 6MWT HR and the RPE were all consistent with data reported in previous studies of hemiplegic patients (24, 25). Both the 6MWT HR and the RPE clearly show that the 6MWT was not very strenuous for the included sample, despite instruction and encouragement. In spite of the fact that the 6MWT was designed to evaluate physical fitness in patients, there was a lack of correlation between 6MWT HR and the 6MWT distance. This confirms the results of a previous study, which showed that the relationship between VO_{2peak} and the 6MWT distance was moderately strong, suggesting that aerobic fitness is a moderate contributor of distance walked during the 6MWT in stroke patients (21). Hence, the use of 6MWT distance alone as an indicator for cardiorespiratory fitness in subjects with stroke cannot be recommended (25).

Several previous studies have shown that factors other than cardiorespiratory fitness influence 6MWT performance in hemiplegic patients (9, 25). Danielsson et al. (9) have shown that the 6MWT distance covered by stroke patients is correlated with the Fugl-Meyer score, but the link between lower limb muscle strength and 6MWT performance has, until now, not been established. In order to evaluate the effect of muscle strength, patients were divided in two groups according to their lower limb muscle strength (MRC sum). The results showed that patients in the LMRC group covered a smaller distance than those in the HMRC despite the similar 6MWT HR and RPE. Moreover, the strong positive correlation between the 6MWT distance and the MRC sum and the stepwise multiple regression clearly showed a strong link between performance during the 6MWT and lower limb muscle strength. In subjects with stroke, impaired function may be related to a combination of spasticity and weakness. Hence, the absence of correlation between 6MWT distance and the spasticity sum-score (MAS) appears to show that the correlation observed by Danielsson et al. (9), between the 6MWT distance and the Fugl-Meyer score could be attributed to lower limb muscle strength.

Finally, the energy cost estimated by the PCI was significantly lower for the HMRC group than for the LMRC group, and significant, but moderate, correlations were found between the PCI and lower limb muscle strength (MRC sum) and 6MWT distance. These results, together with the previous results, appear to show that the energy cost of gait in patients with stroke is strongly related to their lower limb muscle strength, and that performance during the 6MWT is strongly dependent on these two parameters. Hence, the 6MWT should not be used to evaluate the cardiorespiratory fitness of stroke patients (25), but it could be a good indicator of physical capacity and gait efficiency. Because of the role of muscle strength in the performance of the 6MWT demonstrated by our results, we suggest that resistance training and/or combined training (aerobic and resistance) may be appropriate rehabilitation techniques in order to improve 6MWT distance. The 6MWT can also be used to assess the functional repercussions of specific training procedures, which opens up many prospects for future work.

In summary, the 6MWT is not a good predictor of physical fitness in stroke patients because of the large degree of lower limb motor impairment in this population. However, our results clearly show that the 6MWT distance may be a good indicator of lower limb muscle strength and physical gait capacity in stroke patients. The results of the present study have implications regarding the selection and interpretation of tests for the evaluation of walking capacity in stroke patients.

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