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Original research article

Strength of knee flexors of the paretic limb as an important determinant of functional status in post-stroke rehabilitation

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ABSTRACT

Objective: The purpose of the study was to assess the effectiveness of the multi-modal exercise program (MMEP) in patients after stroke, and to identify muscles that are the best predictors of functional performance and changes in functional status in a 3-week rehabilitation program.

Methods: Thirty-one post-stroke patients (60.6 ± 12.7 years) participating in a 3-week MMEP took part in the study. Measurements of extensor and flexor strength of the knee (F_{ext}, F_{flex}) were done. Functional performance was measured using Timed Up & Go test (TUG), 6-Minute Walk Test (6-MWT) and Tinetti Test.

Results: The rehabilitation program improved all the results of functional tests, as well as the values of strength in the patients. Both baseline and post-rehabilitation functional status was associated with knee flexor and extensor muscle strength of paretic but not of non-paretic limbs. At baseline examination muscle strength difference between both $F_{flex}\ kg^{-1}$ and $F_{ext}\ kg^{-1}$ had an influence on functional status. After rehabilitation the effect of muscle strength difference on functional status was not evident for $F_{ext}\ kg^{-1}$ and, interestingly, even more prominent for $F_{flex}\ kg^{-1}$.

Conclusions: MMEP can effectively increase muscle strength and functional capacity in post-stroke patients. Knee flexor muscle strength of the paretic limb and the knee flexor difference between the limbs is the best predictor of functional performance in stroke survivors.

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1. Introduction

Stroke is associated with a number of motor and neuropsychological consequences resulting in a deterioration of functional status and a reduction in the activities of daily living [1,2]. These changes can not only affect muscle weakness, balance and gait, but also result in cognition and mood impairment [1,3].

The muscles of the lower limbs play a key role in maintaining walking ability, keeping balance and rising form the bed or toilet, and as a consequence, in preserving independence in daily life [4]. Most significantly, they are required for an efficient gait, and muscle weakness may be a more important factor limiting gait efficiency (especially gait speed) than spasticity [5,6]. Following a stroke, changes in gait patterns related to asymmetry in step length and time loading, as well as the prolongation of the double support phase, result in lower gait speed and decreased walking endurance [3,7,8]. Several studies have reported correlations between the strength of different muscle groups and such aspects of functional capacity as gait endurance, gait speed or balance in stroke survivors [3,9,10]. Most relevant studies have revealed an association between weakness of the paretic side with functional efficiency [11]. Several authors have observed reductions of muscle strength, not only in the paretic but also the non-paretic side, in comparison to an able-bodied group [2,12,13].

While many training programs have been found to be effective in post-stroke rehabilitation, the precise role of different groups of muscles from the paretic and non-paretic side is still being discussed. As strokes are known to result in a range of impairments, including muscle weakness, reduced endurance, decreased balance, coordination disorders or spasticity, any intended rehabilitation program should aim to influence the underlying impairments, hence the creation of the multi-modal exercise program (MMEP).

Many studies have assessed the effects of different kinds of training on muscle strength or function [14–16], but relatively few assessed prospectively physical functioning in relation to lower limb muscle strength in post-stroke patients [17,18]. Therefore, the purpose of the study was to assess the effectiveness of the multi modal exercise program (MMEP) in patients after stroke and to identify the muscle groups (knee extensors and flexors in both paretic and non-paretic leg) that are the best predictors of functional performance and changes in functional status in a 3-week rehabilitation program. We hypothesized that in this group of patients, the strength of the knee flexor muscles may be more important than that of the extensors, especially on the paretic side.

2. Methods

2.1. Subjects

The study was performed with patients admitted to the Department of Rehabilitation for the purpose of functional rehabilitation more than one month following a stroke. For safety reasons, patients referred to the rehabilitation unit with diagnosis of myocardial infarction or orthopedic surgery established within the previous three months were not included in the study. Furthermore, patients with cardiac contraindications for exercise tests or who lacked the ability to perform tests due to motor system dysfunctions, such as pain, limited range of motion or a spasticity score >2 on a modified Ashworth scale, were excluded from the study. The inclusion criteria comprised the presence of hemiparesis after stroke, the ability to understand and execute commands, and the ability to perform the exercise tests and give written consent to participate in the study. Of the 392 patients hospitalized during a one-year period in the rehabilitation ward, 19 women and 14 men met the inclusion criteria. As two subjects refused to participate further in all the tests, 31 patients aged 27–87 years (60.6 ± 12.7 years) ultimately participated in the study. Baseline characteristics of the study group is shown in Table 1.

Table 1 – Baseline participants' characteristics.

Variable	Mean ± SD	Median (25–75%)
Age (years)	60.7 ± 12.7	59.0 (52.0–72.0)
Sex (male/female)	14/17	
Education (years)	12.8 ± 3.9	12 (10–17)
Number of chronic conditions (including stroke)	3.9 ± 1.9	4 (2–5)
Number of medications	7.5 ± 2.4	7.5 (6–9)
Paretic side (right/left)	11/20	
Type of stroke (ischemic/hemorrhagic)	29/2	
Time after stroke (months)	26.7 ± 38.2	16 (2–30)
Body mass (kg)	75.3 ± 15.1	79 (63–84)
Height (m)	1.66 ± 0.09	1.66 (1.58–1.74)
BMI	27.3 ± 4.6	27.3 (24.4–30.19)
Activities of daily living (ADL; 0–6)	5.32 ± 0.63	5.5 (5–6)

Eleven persons had only undergone primary education, another 11 had left school after completing their secondary education and nine participants had graduated from university. All the patients were diagnosed with stroke, ten with osteoarthritis, nine with coronary heart disease, five with heart failure, two with osteoporosis, one with chronic pulmonary disease, nine with gastrointestinal disease, two with myocardial infarction and two with cancer. Twenty-five subjects were treated for hypertension, 16 for hypercholesterolemia and 10 for diabetes. The average number of medications taken was 7.47 ± 2.40 per day and the pharmacological treatment was maintained during the whole rehabilitation period. The study was approved by the Bioethics Committee.

2.2. Protocol

All the patients underwent physical examination prior to the study. During the interview, information on socio-economic status, smoking, current and previous illnesses and current medication was obtained. The body mass index (BMI, kg m^{-2}) was also calculated. In all 31 patients, two sets of examinations were performed: the first on the first day, and the second three weeks later, on the final day of hospitalization.

All patients participated in a three-week multi-modal exercise rehabilitation program. Physical exercise, divided equally between resistance, endurance and balance training,

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