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Electrical stimulation versus kinesitherapy in improving functional fitness in older women: A randomized controlled trial

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ABSTRACT

Long-stay hospitalized elderly patients frequently develop a decrease in strength, cardiovascular fitness and balance, which can be improved by exercise. Neuromuscular electrical stimulation (ES) might also be effective in this population. The effect of different lower limb rehabilitation programs (3 interventions/week for 6 weeks) on functional fitness in 40 hospitalized old females (82 ± 7 years) were evaluated: kinesitherapy (KT), ES, KT alternated with ES (KT + ES), and no treatment (C). Outcome variables after rehabilitation were: (a) maximal strength of leg extensor and finger flexor muscles; (b) cardiorespiratory fitness (6-min walking test, 6MWT; heart rate, HR); (c) static and dynamic balance and gait skills (Tinetti test). The maximal strength of leg extensor (but not finger flexor) muscles significantly improved in ES (+26%) and KT + ES (+16%) groups only. The distance covered during the 6MWT significantly increased in KT (+15%), ES (+14%) and KT + ES (+9%) groups, but the post-test HR recovery improved in KT group only. Balance (but not gait) skill scores significantly and similarly increased in KT (+11%), ES (+10%) and KT + ES (+11%) groups. In long-stay hospitalized old females ES and KT + ES improved lower limbs isometric strength. Walking ability was improved by all treatments, whereas cardiovascular performance and recovery were ameliorated by KT only.

1. Introduction

Long-stay hospitalized old patients frequently develop a rapid decrease in muscular strength, cardiovascular fitness and balance, as reported in many observational studies (Gillick et al., 1982; Warshaw et al., 1982; Hirsch et al., 1990; Inouye et al., 1993). Such a decline is usually a consequence of limited physical activity (Gillick et al., 1982; Creditor, 1993; Inouye et al., 1993) and occurs early, within a few days after the admission (Lazarus et al., 1991), regardless of the underlying pathology. Therefore, interest is growing in investigating the possible interventions, such as physical exercise, which could limit musculoskeletal and cardiopulmonary decline in long-stay hospitalized adults (Vuori, 1995). This aspect is particularly relevant in women, as they are at greater risk of motor impairment, due to a sex-related decline in muscle strength (Rantanen et al., 1994). It is therefore important for hospitalized elderly women to exercise regularly to maintain and/or recover their functional fitness.

Many studies showed that an exercise intervention improves functional fitness in hospitalized older women (Nichols et al., 1995; Nakamura et al., 2007). A protocol consisting of isometric and isotonic voluntary contractions of upper limbs, trunk and lower limb muscles was generally adopted in these studies.

Neuromuscular electrical stimulation has also been successfully employed in many rehabilitative programs in the last decades. ES increases muscle strength, induces changes in muscle fiber composition and capillary system structure, prevents muscle atrophy due to the prolonged immobilization (Mysiw and Jackson, 2000), decreases pain (Durmus et al., 2007) and increases functional fitness (Mysiw and Jackson, 2000; Pekindil et al., 2001). Moreover, ES seems to be particularly indicated in patients with difficulty or contraindications to perform a voluntary exercise program, e.g. after surgery, or in subjects who are not familiar with active, voluntary exercise (Mysiw and Jackson, 2000). Finally, ES was recently shown to be an effective rehabilitative approach in patients with complex pathologies, such as chronic obstructive pulmonary disease

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(Neder et al., 2002) and congestive heart failure (Quittan et al., 2001). In these conditions the purpose of ES is not only to increase muscle strength, but also to reduce effort during daily activity and to consequently improve self-sufficiency.

However, only few studies so far focused on the different effects of voluntary contraction exercise versus ES on functional fitness in hospitalized elderly patients. In addition, most studies targeted only specific pathologies, e.g. rheumatoid arthritis, osteoarthritis, etc. (Durmus et al., 2007; Piva et al., 2007). Finally, no studies addressed the question whether the effects of the two rehabilitative procedures could be additive when combined.

Aim of this study was therefore to assess the effects of a voluntary versus electrically induced contraction protocol, alone or in combination, in enhancing the different components of functional fitness (muscle strength, cardiopulmonary performance, balance and gait ability) in a group of long-stay hospitalized old women.

2. Subjects and methods

2.1. Subjects

Long-stay hospitalized old women were screened for eligibility according to the following inclusion criteria: (1) age $\geq$75 years; (2) hospital stay duration of at least one month; (3) autonomous ambulation; (4) absence of severe cognitive disorders, as assessed by routine clinical tests for this patient population (Mini Mental State Examination, MMSE $>$ 24/30 and Barthel Index $>$ 70/100). The MMSE (Folstein et al., 1975) is a 30-item questionnaire assessing cognitive functions. The Barthel Index (Mahoney and Barthel, 1965) measures the level of patient independence in 10 activities of daily living: feeding, transfers, personal self-care, toilet transfers, bathing, walking, stairs climbing, dressing and bladder and bowel continence.

Exclusion criteria were: (1) history of acute stroke; (2) any clinical condition contraindicating mobilization (e.g. deep vein thrombosis, fractures, etc.); (3) physical inability to ambulate or exercise; (4) severe cardiopulmonary diseases; (5) metabolic/vascular diseases which could impair walking, as diabetes complicated with macroangiopathies, vascular obstructive pathologies causing claudicatio intermittens, etc.

Fifty-seven age-eligible patients were initially screened in a single rehabilitation centre (the Don C. Gnocchi Foundation, Milan, Italy) from January 2006 to July 2007. Forty (age: 82 $\pm$ 7 years, body mass: 59.5 $\pm$ 12.3 kg, stature: 152 $\pm$ 7 cm, mean $\pm$ S.D.) of these subjects were eligible for inclusion and were randomized (see Fig. 1 for detailed study design). Among the eligible subjects, 19 patients were hospitalized for cardiovascular diseases (arterial hypertension, chronic venous insufficiency, chronic cerebrovascular disease, etc.), 16 for orthopedic pathologies (poliarthroses, osteoporosis, arthritis, etc.) and 5 for neurological diseases (mild cognitive impairment, depressive syndrome, etc.) (see Table 1 for demographic characteristics of enrolled patients). After receiving a full explanation of the purpose of the study and of the experimental procedures, all subjects signed a written informed consent. This study was approved by the ethical committee of the Don C. Gnocchi Foundation and performed according to the principles of the Declaration of Helsinki.

2.2. Study design

This study was a randomized, assessor blinded, controlled trial (Fig. 1). All measures were performed by two investigators, who were blinded to the group allocation of participating subjects. Due to the nature of the treatments, patients and therapists were not blinded.

2.3. Randomization

A simple randomization procedure, based on a computerized random number generator, was used for treatment allocation. As the effects of the different rehabilitative programs were unlikely to be affected by age and anthropometric features of the patients, randomization was not stratified for these characteristics. Nevertheless, all groups resulted to be matched for age and anthropometric characteristics after randomization (Table 1).

Three groups were assigned to 3 different rehabilitation programs (Fig. 1): (1) kinesitherapy applied to lower limbs (n = 10), (2) electrical stimulation of lower limbs (n = 10) and (3) KT alternated to ES (KT + ES; n = 10). The fourth group did not perform any specific training, and was considered as control (C; n = 10). Each program consisted of 18 training sessions of similar duration (45 min), administered 3 times a week, with at least a day of recovery between two consecutive sessions, for a total duration of 6 weeks. All training sessions were carried out by the same physical therapist.

2.4. Rehabilitation programs

The KT program aimed at improving trophism and strength of lower limbs, in particular of leg extensor muscles. Each training session started with a moderate active warm-up, consisting of a 8-min cycling exercise at the 50% of maximal theoretical heart rate, calculated according to Tanaka et al. (2001) equation. According to the ACSM-AHA guidelines for physical activity in older adults (Nelson et al., 2007), the muscle-strengthening exercises included both isotonic and isometric contractions. For isotonic exercises, a load allowing the subject to perform a series of 15–20 repetitions was used. Each isotonic exercise was performed 3 times, with a rest of at least 2 min between each series. For isometric exercises, contractions were kept for 6–10 s for 10–15 repetitions. Each isometric exercise was performed 3 times, with a rest of at least 2 min between each series. Both isotonic and isometric sessions ended with a 10 min passive stretching of lower limb muscles.

The ES program aimed at strengthening the quadriceps muscle and improving its endurance (Caggiano et al., 1994; Laborde et al., 2004). The ES group underwent 18 electrical stimulation sessions of the quadriceps muscle of both legs. Subjects were seated on a chair with the hip and knee placed at 75° of flexion. The ankle was stabilized with an external support to prevent any isotonic contraction of the quadriceps muscle. An electrical stimulator (mod. Compex 2, Compex, Geneva, Switzerland), delivering compensated, bi-phasic square-waves, was used. Each ES session started with an active warm-up, similarly to the KT protocol. Rectangular cathodes (10.4 cm $\times$ 5.2 cm) were applied on the most proximal motor point of the vastus lateralis, vastus medialis and rectus femoris muscles, whereas a square anode (5.2 cm $\times$ 5.2 cm) was positioned proximally on the thigh. Stimulation amplitude was set at each subject's point of discomfort and was adjusted before each session. Stimulation frequency was increased from 35 Hz for the first six sessions, to 75 Hz for the following six (7th to 12th) and to 85 Hz for the last six (13th to 18th) sessions, according to the manufacturer's instructions. A passive stretching routine similar to the one used for the KT protocol was finally administered.

The KT + ES program consisted of 9 sessions of KT and 9 sessions of ES, alternately administered.

The C group was used as control and underwent routine passive rehabilitative procedures only.

2.5. Outcome measures

The four main components of functional fitness, as defined by Nakamura et al. (2007) were used as outcome measures. Each