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Concurrent strength and endurance training exercise sequence does not affect neuromuscular adaptations in older men

Eurico Nestor Wilhelm [a,b,*], Anderson Rech [a], Felipe Minozzo [a], Cintia Ehlers Botton [a], Regis Radaelli [a], Bruno Costa Teixeira [a], Alvaro Reischak-Oliveira [a], Ronei Silveira Pinto [a]

[a] *Exercise Research Laboratory, School of Physical Education, Federal University of Rio Grande do Sul, Porto Alegre, RS, Brazil*
[b] *Centre for Sports Medicine and Human Performance, Brunel University London, Uxbridge, UK*

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ABSTRACT

Concurrent training is an effective method for increasing skeletal muscle performance in aging individuals, but controversy exists as to whether chronic neuromuscular and functional adaptations are affected by the intra-session exercise sequence. Therefore the aim of this study was to evaluate the effect of concurrent endurance and power-like strength training exercise sequence on muscular and functional adaptations of older participants. Thirty-six healthy older men not engaged in systematic exercise training programs for at least 6 months were divided into a control group (CON; 65.8 ± 5.3 years), or in the training groups: endurance–strength (ES; 63.2 ± 3.3 years), or strength–endurance (SE; 67.1 ± 6.1 years). Training groups underwent 12 weeks of concurrent endurance and power-like strength training, starting every exercise session with either endurance (in ES) or strength (in SE) exercises. Measurements included knee extension one repetition maximum (1RM), knee extension power, 30 second sit-to-stand test (30SS), maximum vastus lateralis surface electromyographic activity, and rectus femoris echo intensity (RFEI). Significant increases in maximal strength (ES +18 ± 11.3%; SE +14.2 ± 6.0%; $p \leq 0.05$), peak power (ES +22.2 ± 19.4%; SE +26.3 ± 31.3%; $p \leq 0.05$), and 30SS performance (ES +15.2 ± 7.2%; SE +13.2 ± 11.8%; $p \leq 0.05$) were observed only in the training groups, with no differences between ES and SE. Maximum muscular activity was greater after 12 weeks at training groups ($p \leq 0.05$), and reductions in RFEI were found only in ES and SE ($p \leq 0.05$). These results demonstrate that concurrent strength and endurance training performed twice a week effectively increases muscular performance and functional capacity in older men, independent of the intra-session exercise sequence. Additionally, the RFEI decreases indicate an additional adaptation to concurrent training.

1. Introduction

Aging progressively reduces aerobic capacity (Izquierdo et al., 2001), skeletal muscle strength (Lynch et al., 1999) and power levels (Izquierdo et al., 2001), resulting in functional impairment for this population (Jones et al., 1999; Suzuki et al., 2001), but exercise training is an effective intervention to counteract part of these effects (Cadore et al., 2012a, 2013; Holviala et al., 2012; Izquierdo et al., 2004; Karavirta et al., 2011).

Strength training performed with high voluntary velocity, such as during power exercises or in variations of traditional strength exercises, has been reported to generate superior power gains than traditional strength training in older men while causing similar or even greater neuromuscular and functional adaptations (Bottaro et al., 2007; Fielding et al., 2002; Marsh et al., 2009; Nogueira et al., 2009). On the other hand, concurrent training (the combination of endurance and strength exercises) results in overall fitness improvements in aging participants (Cadore et al., 2010, 2012a; Holviala et al., 2012; Karavirta et al., 2011), thereby the inclusion of power exercises in concurrent training programs has been a useful strategy to improve chronic neuromuscular adaptations in young and older participants (Häkkinen et al., 2003; Karavirta et al., 2011).

Concurrent training, however, may hamper rapid (Häkkinen et al., 2003), and maximal (Cadore et al., 2010; Hickson, 1980; Kraemer et al., 1995) strength gains when compared to strength training alone. One possible factor responsible for this interference effect is the intra-session sequence of strength and endurance exercises (Leveritt et al., 1999). Accordingly, Cadore et al. (2012a, 2012b), reported greater neuromuscular adaptations in elderly men undergoing a concurrent training program 3×/week when sessions were started by strength exercise first as opposed to endurance exercise. Although these results suggest that the concurrent training exercise order is an important variable determining training adaptation in older individuals, it is still unknown if the distinct strength gains observed would be enough to

* Corresponding author at: Center for Sports Medicine and Human Performance, Brunel University London, Post code: UB8 3PH, Uxbridge, UK.
E-mail address: euricowilhelm@gmail.com (E.N. Wilhelm).

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lead to different functional adaptations (which ultimately would improve daily life activities). Previous studies in young participants, however, had reported no influence of intra-session exercise sequence on physiological adaptations (Chtara et al., 2008; Collins and Snow, 1993; Gravelle and Blessing, 2000). Therefore, the understanding about the effects of concurrent training exercise sequence still needs investigation.

The beneficial effects of concurrent training to counteract aging-related strength and power losses are mediated by increases in maximal muscular activation (Cadore et al., 2013; Holviala et al., 2012), neuromuscular economy (Cadore et al., 2010, 2013), and skeletal muscle mass (Cadore et al., 2012a, 2013). Less, however, is known about its effects on intramuscular infiltration of non-contractile elements in aging muscles. Muscular echo intensity obtained from ultrasonography images is considered an alternative non-invasive way to investigate the skeletal muscle deposition of non-contractile material (Arts et al., 2010). An increase in echo intensity is thought to be caused mainly by fat infiltration (Arts et al., 2010), and results in a deterioration of muscular performance (Cadore et al., 2012b; Fukumoto et al., 2012; Wilhelm et al., 2014). Although traditional strength training may be efficient to counteract these changes in muscular echo intensity (Radaelli et al., 2013), it remains unknown if concurrent training can cause comparable effects in aging muscles. In addition, previous works that reported diminished adaptations to concurrent training when the sessions started with endurance exercise indicated a predominantly neural interference (Cadore et al., 2012a, 2013). However an altered response in intramuscular non-contractile tissue might have happened in the endurance–strength group, what would be indicative of a morphological interference.

To date no study has sought to determine whether the concurrent endurance and power-like strength training exercise sequence affects neuromuscular and functional adaptations in older participants. The aim of the present study, therefore, was to investigate whether the intra-session power-like strength and endurance exercise sequence influenced these physiological adaptations.

2. Materials and methods

2.1. Experimental design

Participants of the study underwent a 12 week experimental period (concurrent endurance and power-like strength training or non-exercise control) with pre- and post-intervention test measurements (Fig. 1). The pre-testing period was composed of a familiarization session and three testing days, each separated by at least 48 h. Participants were then allocated into one of three groups according to their knee extension one repetition maximum (1RM) value. In the control group (CON), participants did not perform the exercise training intervention; whereas in the exercise training groups the participants performed a concurrent training program starting each exercise session by either endurance exercise in the endurance–strength group (ES); or strength exercises in the strength–endurance group (SE).

2.2. Participants

Forty-six healthy older men not engaged in any systematic exercise training programs for at least 6 months were eligible to participate in the study (Fig. 1). During the pre-testing period, one participant was withdrawn due to health problems unrelated to the study, with the remaining participants distributed between CON, ES and SE. During the 12 week intervention period, 6 participants did not complete the follow-up and 3 participants did not attain the minimum training compliance (i.e. missed more than 3 training sessions), resulting in 13 participants in CON, 11 participants in ES, and 12 participants in SE (Table 1). Only participants that successfully completed all study steps were included in statistical analysis. The study was advertised in two widely-read regional newspapers and all recruited participants were non-smokers free from health problems, including diabetes, hormonal and metabolic diseases. Participants with mild controlled hypertension

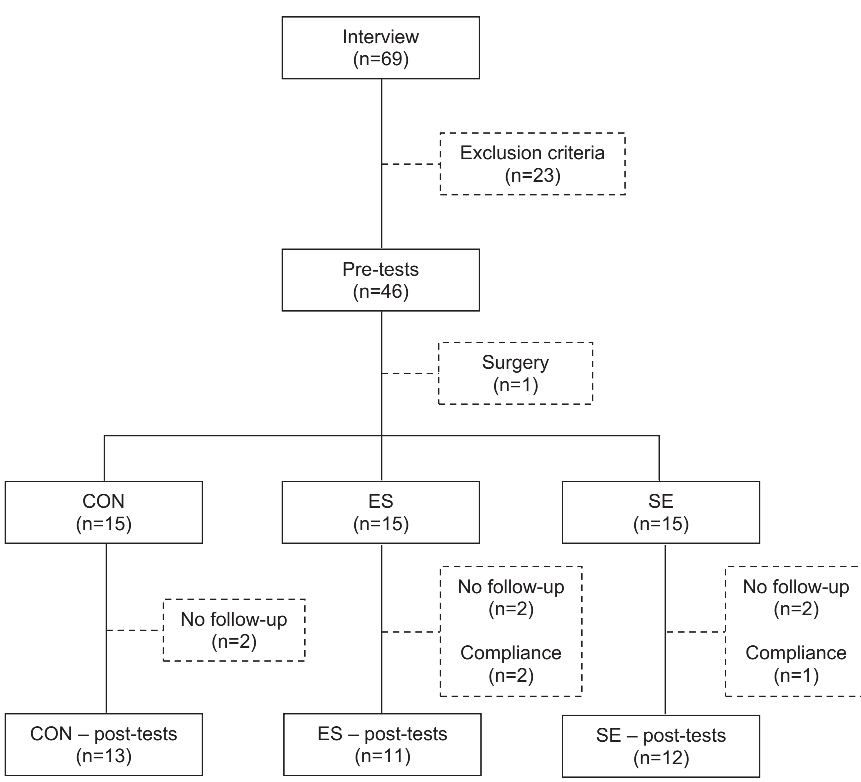

Fig. 1. Flow diagram of the study. CON = control group; ES = endurance–strength group; SE = strength–endurance group. Dashed boxes indicated participants excluded.