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DEVELOPMENT OF MUSCULAR EXPLOSIVE FORCE IN OLDER WOMEN: INFLUENCE OF A DANCE-BASED EXERCISE ROUTINE

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Abstract

Introduction: Human muscle strength and the ability to develop explosive force or power are known to decrease with increasing age. Numerous exercise programs are recommended to oppose this age-related force deterioration. Dance-based exercises have been proposed for older people because they are safe and more likely to optimize adherence to a more active lifestyle. Physical and psychological benefits of a dance-based exercise routine have been reported. However, there have been no reports of the effect of dance-based exercise routines on the ability to develop explosive force.

Aim of the study: The aim of this study was to compare the ability to develop explosive force between older women between older women who participate in a dance-based exercise program compared to older women who do not.

Methods: Twenty active (i.e., participant in dance-based exercise program for at least six months) and 20 sedentary older women were assessed for explosive force through contractile rate of torque development (RTD) (slope of force-time curve) and contractile impulse (CI) (time-integrated force) for the first second (0-250, 0-500, 0-750 and 0-1000ms) of the contraction of the dominant knee extensor of each subject.

Results: The older women engaged in a dance-based exercise program demonstrated greater values of explosive force ($P < 0.05$) than the sedentary older women.

Conclusions: It appears that a dance-based exercise program can have a positive effect on the ability to develop explosive muscular force in older women.

Key words: *Aging, muscle strength, dancing, exercise*

Introduction

Muscle weakness in old age is a physiological process of aging and has been associated with an anabolic-deficient state [1], increases in levels of myostatin [2], decline in protein synthesis [3, 4], changes in content of interleukin-6 and TNF-α [1, 5], reduction of the satellite cells replicative potential [6], changes in size and number of Types IIA and IIB muscle fiber content [4, 7], and changes in the neural output to muscle [4, 8]. The consequences of this weakness may limit independent living and potentially contribute to falls, as well as to other forms of morbidity.

Typically, muscle mass and force reach their peak value between the second and fourth decades of life and then decline steadily with advancing age [9]. The term *sarcopenia* has been used to describe the age-related changes that occur within skeletal muscle and involve changes in the central and peripheral nervous system innervation, altered hormonal status, inflammatory effects, and altered caloric and protein intake [4]. Accordingly, the prevalence of sarcopenia is thought to increase with age [10].

The ability to increase force in short-time periods, also called explosive force (EF), is an important parameter and has important functional significance in many daily activities (11). Explosive force has been studied through the analysis of the first seconds of the moment/time curve. Aagaard et al. [11] postulated that the rate of rise in contractile force at the onset of contraction exerted within the early phase of rising muscle force can provide useful information about muscle function. This response is related to level of neural activation [12], muscle size, and fiber-type (MHC isoform) composition [13]. The same authors stated that the inability to exert a rapid rise in muscle force may increase the incidence of falls related to the impaired control of postural balance with increasing age [11]. Thus, a high rate of rise in contractile force seems to be of vital importance for the ability to rapidly regain balance during sudden postural perturbations, thus reducing the risk of falls, especially in elderly individuals.

Nelson et al. [14] state that a sedentary life style into older age can lead to a loss of functional health due to the deficits in strength, endurance, and flexibility that are consistently related to inactivity. Beneficial effects of exercise in older people are widely described [15-17], but the effect of exercise on the ability to develop explosive force in short-time periods in older people has scarcely been studied [15-18].

Despite the known beneficial effect of exercise programs on older persons; physical limitations, psychological state and exercise program features can influence adherence to such programs [19]. Physical and psychological benefits have been reported in older people after dance-based exercise programs [19-23] and the features of this exercise program seem to be highly acceptable for the senior population [19, 22-25].

Numerous studies have demonstrated increase in explosive force after an exercise training program in senior populations [15-17] but the effects of a dance-based exercise program on explosive force have not been documented. It is expected that a dance-based exercise program would induce neural and muscular adaptations owing to its features, as the amount of concentric, eccentric and/or isometric efforts. Therefore, the aim of this study was to compare the ability to develop explosive force through the rate of torque development in the first seconds of the moment/time curve of older women who participate in dance related exercise programs compared to those who do not.

Material and Methods

Subjects

Forty mature women volunteered to participate in the study. The general eligibility criteria included: (a) living independently in a community, (b) not having any chronic pain complaints; especially in the lower extremities, or (c) not having a history of lower extremity surgery. All subjects gave their informed consent to the procedures of the study. The conditions of the study were approved by the local ethics review committee.

The subjects were divided in two groups called: Dance-based exercise group (DBEG) (n=20; 68±5 years old; height: 149±5 cm; mass: 58±11 Kg; BMI: 26±3 kg/m^2) and Control group (CONT) (n=20; 70±5 years old; height: 152±5 cm; mass; 63±10 kg; BMI: 27±4 kg/m^2) according to their physical activity status (i.e., active or sedentary). The DBEG group was composed of older women with at least 6 months (8±2 months) of experience in a dance-based exercise program, and the CONT group was composed of older women without any experience in dance-based or any other exercise program at least one year before the study.

Exercise program

The dance-based exercise program was an exercise routine designed to increase balance, strength, locomotion/agility and motor processing and include concentric, eccentric and isometric actions during many movements. This included squats, lateral, anterior, and posterior displacements and others. Exercise classes were held 3 times a week with at least one day of rest between classes. Each 60-minute class began with 10 minutes of warm-up activities consisting of calisthenics and stretching, followed by 35 minutes of dance-based exercises and finished with 10-15 minutes of cool-down activities. The class movements consisted of pre-determined choreography following traditional Brazilian music (Samba). An experienced instructor was present during the exercises to stimulate the subjects with verbal encouragement and to make the sessions enjoyable. The intensity varied for each participant depending on the individual's actual fitness status and on perceived exertion using the Borg CR10. The intensity was evaluated by the experienced instructor and the goal was to maintain vigorous exercise but without pain or discomfort. All subjects belonging to the DBEG performed at least 95% of all classes.

Instruments and procedures

Strength assessments were performed using a knee extension machine, adjusted to fit individual anthropometric characteristics, adapted with thoracic and abdominal stabilization straps. Each subject performed three maximum isometric voluntary contractions (MIVC) of knee extensors lasting 2 seconds was captured by a load cell (EMG System, São Paulo, Brazil) at a sampling rate of 2 kHz. At the beginning of the testing procedure, three warm-up contractions were performed prior to the maximal test actions. It was adopted a rest interval of 2 minutes between MIVC trials and the best performance (i.e., higher MIVC) was used to explosive force analysis. The dominant leg as reported by each subject was positioned at 90ş of static knee flexion (0ş = full knee extension). Subjects were carefully instructed to contract "as fast and forcefully as possible". The subjects were naive to the experimental procedures in order to mitigate a potential "learning effect".

During later off-line analysis, the strain-gauge signal was smoothed by a digital fourth-order, zero-lag Butterworth filter, by using a cutoff frequency of 15 Hz (11) and the capacity to increase force in short-time periods was determined as the area under the moment-time curve in time intervals of 0-250, 0-500, 0-750, and 0-1000 ms relative to onset of contraction. The cumulated area under the moment-time curve reflects the entire time history of the contraction(s) and can be called as contractile impulse (CI) [11]. The average slope of the moment-time curve (Δmoment/Δtime) over the time intervals of 0-250, 0-500, 0-750, and 0-1000 ms relative to the onset of contraction was calculated, and is representative of the rate of torque development (RTD) [11]. The analysis of the moment-time curve from the MVIC provides relevant information about muscle strength features.

Statistics

Normality of data distribution was assessed using the Kolmogorof-Smirnov test. As the normality test demonstrated a normal distribution for all studied variables the values of RTD and contractile impulse (CI) of DBEG group and the CONT group were compared using Student´s t-test for unpaired samples (two-tailed, 0.05 level of significance).

Results

The DBEG demonstrated higher values of contractile impulse at all time intervals analyzed (0-250 ms: 5.5±2.0 N.m.s, 0-500 ms: 25.4±9.1 N.m.s, 0-750 ms: 55.2±14.9 N.m.s and 0-1000ms: 89.8±24.8 N.m.s) when compared to CONT group (0-250 ms: 3.1±2.1 N.m.s, 0-500 ms: 16.1±7.1 N.m.s, 0-750 ms: 37.8±11.0 N.m.s and 0-1000 ms: 65.0±15.0 N.m.s) ($P < 0.05$), as shown in Figure 1.

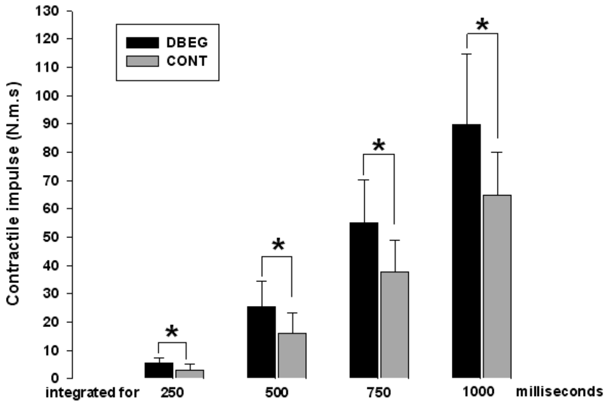

Fig.1. *Means ± SD of contractile impulse of the Dance-based exercise group (DBEG) and control (CONT) group. Contractile impulse, defined as the area covered by the moment-time curve, was calculated for the time intervals of 0–250, 500, 750, and 1000 ms from the onset of contraction. (*) Significant difference (P < 0.05)*

The analysis of the rate of torque development (RTD) demonstrated that DBEG (0-250ms: 230.5±60.0N.m.s, 0-500ms: 223.2±44.9N.m.s, 0-750ms: 183.4±41.0N.m.s and 0-1000ms: 147.1±35.0N.m.s) was able to develop explosive force better than CONT group (0-250ms: 123.7±58.9N.m.s, 0-500ms: 141.8±35.9N.m.s, 0-750ms: 133.6±27.0N.m.s and 0-1000ms: 110.0±27.0N.m.s) at all time intervals analyzed (Fig. 2) ($P < 0.05$). The largest difference between DBEG and CONT group was observed in the initial interval (0-250ms) with an average difference of 107 $N.m.s^{-1}$, and the smallest difference between groups was observed in the last measured interval (0-1000ms) with an average difference of 37 $N.m.s^{-1}$.

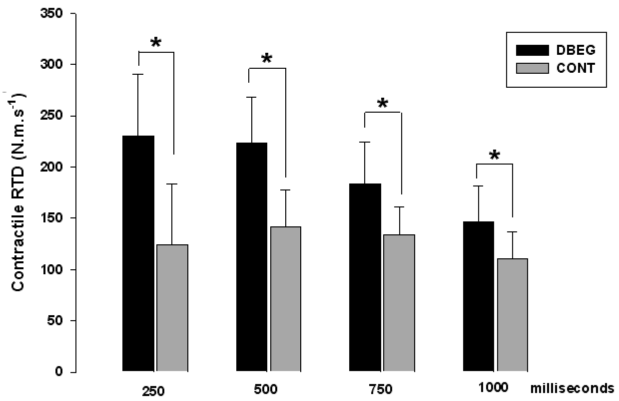

Fig. 2. *Means ± SD of contractile RTD of the Dance-based exercise group (DBEG) and control (CONT). Contractile RTD was derived as the average slope of the moment-time curve (Δmoment/Δtime) over the time intervals of 0–250, 500, 750, and 1000 ms relative to the onset of contraction. (*) Significant difference (p < 0.05)*

Discussion

The present study investigated the explosive force characteristics of the dominant leg knee extensor muscle group in a group of older women who had participated in a dance-based exercise training and a control group who did not participate of the proposed exercise program. The findings demonstrated that the DBEG had a higher capacity to develop explosive force compared to the CONT group.

Lee et al. [7] identified that fast-twitch muscle fibers (Types IIA and IIB) decrease in area, number, and size with increasing age. These authors postulated that the decrements in the fast-twitch fibers may be a result of decreasing muscle activity; that is, as lack of physical activity or regular exercise. Our results support this postulate since fast twitch muscle fibers are highly related to the capacity to develop explosive force. However, in addition to muscle size and fiber-type (MHC isoform) composition, the capacity to develop explosive force in short-time periods may be influenced by the level of neural activation [12]. Thus, adaptations of the nervous system associated with training (like the learning effect) cannot be neglected and could in part explain the faster rates of explosive force development of the DBEG. To this point, Aagaard et al. [11] described that exercise training induces neural adaptations such as alterations in motoneuron recruitment and firing frequency, as well as increased incidence of discharge doublets [11] which can explain the faster rates of explosive force development of the DBEG.

Aagaard et al. [11] also demonstrated an increase in muscle activity through electromyography during the first milliseconds of a moment/time curve after an exercise training program. This finding was associated with the increase in the rate of rise in contractile force indicating changes in efferent neural drive in the very early phase of rising muscle force. The faster RFD in the DBEG in this study, with greatest values in the very early phase of increasing muscle force, support the findings of Aagaard et al. [11].

The physical performance of senior populations has been studied through functional tests (e.g. 20-m walk, six-min walk, stair climbing, chair rise, keeping a half-squat position, Timed Up & Go Test, 30-second chair stand and others) or via the measurement of peak force reached during an isometric contraction [21, 23, 24, 26]. However, the contractile impulse is perhaps the single most important strength parameter because it incorporates the aspect of contraction time, which is neglected using most other strength parameters [11].

The increased explosive force in the DBEG could be related to the training program characteristics of the dance-based exercise program, which could have improved the neural adaptations [21, 24], especially because the dance-based exercises demand fast changes in body position, similarly to balance training, which requires fast neural activation to generate force to maintain balance and avoid falls. In a recent review Granacher et al. [20] hypothesized that the balance training by perturbation-based training programmes could be efficient in terms of fall prevention and gains in explosive force and our results can corroborate this proposed hypothesis. Additionally, numerous dance movements employ eccentric efforts like used in plyometric exercises what induce an eccentric preload on muscle and induce a myotatic stretch reflex leading to a more forceful concentric contraction [21]. Valour te al. [28] demonstrated the benefits of eccentric training in older women and stated that the gains in strength would likely result more from intramuscular modifications than from changes in muscular activity.

The ability to generate explosive force has been associated with functional status in the aged, and is thought to contribute to better performance in tasks such as chair rising, stair climbing, fast walking, and fall prevention [29]. In addition, it may reduce the incidence of falls related to the impaired control of postural balance with increasing age (11). Numerous studies [20-22, 27] have been stated that greater physical activity in older women could lead to a greater prevention of falls and improve the performance in daily tasks. Additionally, dance-based exercises have been recommended for older adults because it has a relatively low incidence of injuries and have a good acceptance by this population [21].

Physical activities for the elderly should be tailored to the individual's specific needs and interests to ensure maximal enjoyment and optimize adherence to the physical activity regimen. Long-term adherence can be enhanced by making physical activity a part of one's lifestyle. Dance group-based physical activity provides several advantages, including enhanced adherence through social interaction with others and mutual commitment to physical activity among friends, opportunities for instruction in proper technique, and qualified supervision [25]. Judge [22] stated that programs such as Tai chi and social dance look promising as well maintained exercise activities for the elderly owing to their benefits and to their acceptance by the senior population.

Certain limitations exist within the present study and are acknowledged. The use of a cross-sectional design limits the conclusions about the effect of the proposed exercise program. This could have been rectified by using a prospective design. Unfortunately, the studied sample was not available at the beginning of the exercise program. Thus, at this time we cannot support a "cause and effect" conclusion from our data. Nonetheless, it is clear from our data that older women involved with a dance-based exercise program for at least 6 months, were able to develop greater explosive force than sedentary a group not participating in any exercise program.

It appears that a dance-based exercise program could have a positive effect on the ability to develop explosive force in older women, which could reduce some of the functional decline associated with aging muscle performance. It is recommended, however, that future studies employ prospective designs in order to more definitively study the influence of a dance-based exercise program on the explosive force development of older men and women.

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