ORIGINAL PAPER (ARTIGO ORIGINAL)

HOME-BASED STRENGTH TRAINING INCREASE ELECTROMYOGRAPHIC ACTIVITY AND POWER IN ELDERLY

TREINAMENTO DE FORÇA HOME-BASED AUMENTA A ATIVIDADE ELETROMIOGRÁFICA E POTÊNCIA EM IDOSOS

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ABSTRACT
ASSUMPÇÃO, C. O.; PRESTES, J.; LEITE, R. D.; URTADO, C. B.; BATHOLOMEU NETO, J.; MONTEBELO, M. I. L.; BORIN, S. H.; LEITE, G. S.; PELLEGRINOTTI, I, L. Home-based strength training increase electromyographic activity and power in elderly. Brazilian Journal of Biomotricity, v. 3, n. 3, p. 231-242, 2009. The purpose of this study was analyze the effects of strength training on quadriceps muscle electromyographic activity and lower limb power in elderly women. 28 female volunteers aged 65.5 ± 3.6 years old were submitted to strength training for 12 weeks with a frequency of twice a week and were divided into: G1P (n=16, periodized group) and G2NP (n=12, non-periodized group). Electromyographic activity of vastus medialis oblique (VMO), vastus lateralis longus (VLL), oblique (VLO), rectus femoris (RF) muscles in knee extension movement, root mean square (RMS), median frequency (MF) were determined and lower limb power was analyzed by the jump test. There was an increase of RMS in the 30º knee flexion angle in
VLO for both limbs and an increase of RMS in the 90° knee flexion angle in VLO and VMO for G1P. G1P increased MF in the 30° angle in VMO. In the 90° angle there was an increase in VMO MF, and lower limb power for the G1P group. Conclusions: Strength training periodization positively, influenced electromyographic activity and lower limb power in elderly women.

Key words: elderly, strength training, power, electromyographic activity

RESUMO

O propósito do estudo foi analisar os efeitos do treinamento de força na atividade eletromiográfica no músculo quadríceps e potência de membros inferiores em mulheres idosas. 28 voluntárias com idade de 65,5 ± 3,6 anos foram submetidas ao treinamento de força durante 12 semanas, duas vezes por semana e divididas em: G1P (n=16, grupo periodizado) e G2NP (n=12, grupo não-periodizado). Atividade eletromiográfica dos músculos vasto medial obliquo (VMO), vasto lateral longo (VLL), obliquo (VLO), reto femoral (RF) no movimento de extensão do joelho, raiz quadrada da média dos quadrados (RMS), frequência mediana (FM) foram determinados e a potência de membros inferiores foi analisadas pelo jump test. Houve um aumento da RMS na flexão de joelho no ângulo de 30° no VLO para ambos os membros e um aumento da RMS na flexão de joelho no ângulo de 90° no VLO e VMO no G1P. G1P aumento FM no ângulo de 30° no VMO. No ângulo de 90 houve um aumento na FM no VMO e potência de membros inferiores para o grupo G1P. A periodização do treinamento de força influenciou positivamente atividade eletromiográfica e potência de membros inferiores em mulheres idosas.

Palavras-chaves: envelhecimento, treinamento de força, potência, atividade eletromiográfica.

INTRODUCTION
With the increase in life expectancy, the population of elderly individuals has progressively increased, corresponding to approximately 7% of world population (VAN DER BIJ et al., 2002). The practice of physical exercise can improve the functional capacity and life span of the elderly (ELLINGSON and CONN, 2000). On the other hand, sedentarism is a risk factor that can induce chronic health problems, such as cardiovascular disease, hypertension, obesity, osteoporosis, type II diabetes, sarcopenia (decrease in sarcomere number) (VAN DER BIJ et al., 2002).

Among the degenerative processes associated with aging, the following are emphasized: degeneration of the central nervous system (decrease in neural drive, muscle excitability and myoneural junction), decrease in aerobic capacity, hormone secretion, sarcopenia and loss of muscle force, which can affect men and women (BARRY & CARSON, 2004) Strength is an important factor inherent to functional capacities, so that in the elderly, dramatic reductions are observed after 70 years of age (particularly in the lower limbs), accompanied by concomitant decrease of 30-40% in muscle mass around 80 years of age (especially in type II muscle fibers)(GRIMBY and SALTIN, 1983; JANSSEN et al., 2000; VANDERVOOT, 2002). Muscle weakness can completely compromise common daily physical activities (HAKKINEN et al., 1997).

In this sense, strength training has been used to attenuate the above-mentioned degenerative processes, since this type of intervention can induce significant increase in strength, muscle fiber cross-sectional area, bone mineral density and neuromuscular activation (SEYNNES et al., 2004). The neural adaptations induced by strength training in the elderly involve the increase in neural drive to agonist muscles (increase in recruitment and firing rate of motor units), improvement of coordination between agonist and synergist muscles and decrease in the agonist/antagonist coactivation (BARRY and CARSON, 2004). Häkkinen et al. (2001) evaluated the surface electromyographic activity (EMG) of quadriceps muscle in elderly women (64 years old). The strength training was performed with 40-70% of 1RM, two sessions per week for 21 weeks. The authors concluded that the intervention induced an increase in knee extensor EMG.
Several studies have shown the efficiency of strength training with specific machines and devices (SEYNNES et al., 2004; HÄKKINEN et al., 2001; TRAPPE et al., 2002). However, some elderly individuals do not have access to weight training machines or places that have this type of equipment. Thus, it is important to evaluate the feasibility and the implementation of strength training programs with alternative methodologies that could be available to the elderly population in various places and at reduced costs.

Based on the above mentioned information, the aim of the present study was to analyze the effects of home-based strength training on neuromuscular variables in elderly women, by evaluation of the electromyographic activity of the quadriceps and lower limb power.

METHODS

- Subjects

Twenty-eight women volunteers were engaged in the present study. They were 65.5 ± 3.6 years old and were participants of the physical activity program proposed by the Physical Education, Sport and Recreation Center of the Superior School of Agriculture “Luiz de Queiroz” (ESALQ-USP). All participants signed an informed consent document which was approved by the Methodist University of Piracicaba Research Ethics Committee for Human use (Protocol No.: 60/05).

The individuals had a minimum of one year of physical activity background, with two weekly sessions and were randomly divided into two groups: periodized group 1 (G1P) composed of 16 women with mean body mass and height of 66.16 ± 5.77 and 1.55 ± 0.03, respectively; and the nonperiodized group 2 (G2NP) composed of 12 women with mean body mass and height of 65.95 ± 3.71 and 1.58 ± 0.03, respectively.

The participants in G1P had their physical exercise program modified, so that it was planned in periods (periodization). Whereas the participants in G2NP continued with their regular exercise program.

- Training Design

The training program for G1P was composed of three periods of four weeks each (mesocycles A, B and C, Figure 1), distributed into a physical conditioning program of 24 sessions, with a total 12 weeks of intervention. The evaluations were performed before the training intervention (T1) and in the weeks 4, 8 and 12 (T2, T3, and T4, respectively) (Figure 1).

The content of exercises and order for the training sessions were different in each of the three mesocycles. The first training phase, mesocycle A was characterized by strength development to obtain neuromuscular adaptation, so that there was emphasis on learning to perform the movements correctly. The average duration of the training sessions was 50 minutes and of the repetitions 3-4s, taking into account the concentric and eccentric phases of the movement. All sessions were individually supervised by a strength and conditioning specialist.

Mesocycle A was composed of training sessions A and B (Table 1), with 2 sets of 15 repetitions in each proposed exercise for the lower body (LB), alternating with 2 sets in each proposed exercise for the upper body (UB) and a rest interval of 10-20 seconds between exercises. In total, 24 exercises for LB and 16 exercises for UB were performed. The volume of this period was 360 repetitions for LB and 240 repetitions for UB.

The aim of Mesocycle B was to increase strength, providing the improvement of power specific components. This mesocycle was composed of training sessions B, C and D
Table 1), which had 2 sets of 15 repetitions for each proposed exercise, totaling 24 exercises for LB and 16 exercises for UB. The calculated volume was the same as it was for mesocycle A. In this period, four B training sessions were performed, the same as in mesocycle A. The other four training sessions C and D had 6 sets of 15 repetitions for LB, alternating with 4 sets for UB, and rest interval of 10 seconds between exercises.

Mesocycle C was composed primarily (2 weeks/4 bouts) of training sessions E and F, which had sets of 15 repetitions for each proposed exercise, totaling 32 exercises for LB and 8 exercises for UB. The volume of this period was 480 repetitions for LB and 120 repetitions for UB.

In this sequence, four training sessions were performed (E and F) that had 8 sets of 15 repetitions for LB, alternating with 2 sets for UB, without a rest interval between exercises. The second phase of mesocycle C (2 weeks/4 bouts) was composed of training sessions G and H that had sets of 15 repetitions for each proposed exercise, totaling 24 exercises for LB and 16 exercises for UB. The volume of this period was 360 repetitions for LB and 240 repetitions for UB.

This phase was composed of 2 sets of 15 repetitions LB, alternating with 2 sets of 15 repetitions for UB. In all mesocycles, in the beginning and at the end of the training sessions static stretching exercises for LB and UB were performed in pairs.

The volunteers of the nonperiodized group (G2NP) participated in their normal exercise program, without interference of the training program proposed by the present study, with exception of the testing periods that were conducted for both groups. Resistance exercises for LB and UB were performed. To perform the exercises, the volunteers used wood sticks, elastic bands and tennis balls. The main objectives of the training for the G2NP were to maintain physical capacity, relaxing and socialization, but without the periodization and training control applied to G1P.

<table>
<thead>
<tr>
<th>Training program</th>
<th>Mesocycle A</th>
<th>Mesocycle B</th>
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<tr>
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<td>Day 2</td>
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<td>Evaluations</td>
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Figure 1 - Framework of the training days and sessions applied (periodization)

- Electromyographic Evaluations

The electromyographic evaluations were performed in two phases: before the training program started (T1) and after three months of training (T4), so that root mean square (RMS) and median frequency (MF) values were evaluated. These measures provided the amplitude value of the electromyographic signal in the vastus medialis oblique (VMO), vastus lateralis longus (VLL), vastus lateralis oblique (VLO) and rectus femoris (RF) muscles.

The exercise was performed in the BONNET, CARCi® extensor chair, which allows the LB to be fixed at different knee flexion angles, providing an isometric contraction (IC). The load cell was fixed in the mobile arm of the extension chair, so that the volunteer performed a maximum voluntary isometric contraction (MIVC) of the knee extensor muscles. The load cell was positioned perpendicularly to the movement axis, according to the proposals of Basmajian and De Luca (1985). The measure was done in MIVC, with a
previous adaptation before the acquisition, to familiarize the individual with the experimental procedure.

The volunteers remained in the seated position with the trunk positioned against the extensor chair support, with the hip joint in 90º and at 30º of knee flexion. For the measurement at the 30º knee flexion angle, the universal goniometry was used (CARCI®). Before starting the measures at the 30º angle, the foot was placed on a support apparatus to ensure that the body segment to be evaluated was comfortable and relaxed. The same procedure was used for the 90º knee flexion angle. The technical procedures were followed according to Hermens et al. (2000)

The electrode on the VMO muscle was positioned on the muscle belly at an inclination of 55º (HANTEN and SCHULTHIES, 1990). For the VLO and VLL muscles the inclinations were of 50º and 13.6º respectively and for RF muscle the electrode was positioned parallel to the muscle fibers (CRAM et al., 1998. The electrodes were positioned on the skin previously tricotomized and cleaned with a 70% alcohol solution to remove oiliness and impurities.

With the purpose of minimizing and eliminating any possible artifacts in the electromyographic recording, a reference electrode was fixed with an electro-conductor gel in tibia tuberosity region and was linked to one of the electromyography system channels. The electromyography system used was the Lynx® EMG1000 model, with 15 signal conditioners, with 11 bio-potential channels (6 passive and 5 active) and 5 for instrumentation, $10^3$ Ohms impedance, 16 bits of resolution and the input range of ± 5V, interpolated with a Pentium III microcomputer.

The channels for electromyographic signal acquisition presented auto-adjustment for amplification, with a maximum of 1000 times, irrespective of the electrode type. The signals were collected for a period of up to 5 seconds, previously determined by AqDados® software, with three MIVC at each angle and for both limbs. The volunteer initiated the contraction and after two seconds the signal caption was started. This interval allowed the participant to perform a homogeneous isometric contraction during the entire period of signal caption. The starting point of the contraction was determined by the evaluator’s verbal command and was followed by one minute rest intervals between each contraction.

- Jump Test (Lower body power)

For this test the jump test system, composed of a jump platform connected to a computer, was used. The volunteers remained in the standing position, on the platform, with the arms free to assist in the jump movement. In this position the participant performed a little knee flexion and jumped. Three attempts were performed and the best score was used to determine the vertical jump. Jump test was evaluated on four occasions: before the training program started (T1), after four weeks (T2), eight weeks (T3) and after three months of training (T4).

- Statistical Analyses

The statistical analyses began with the Shapiro-Wilk normality test and by the homocedasticity test (Levene criteria). To check differences between groups, for each electromyographic variable the variable difference (T4 – T1) was created, in which the Student’s-t test was used for homocedasticity variables; otherwise the corrected t test was used (Welch correction). For lower body power the Anova-Friedman test was applied. When the variables presented statistical significance the analysis was followed by application of the Rank test. The analyses were processed with the software SPSS® version 7.5 and BioEstat 3.0, with a critical level of 5% (p≤0.05).
RESULTS

- Root mean square (RMS) in the 30º and 90º angles of knee flexion

There was a significant increase in RMS at the 30º knee flexion angle for VLO in both limbs of G1P (from 60.1 to 77.5µV in the left lower limb and from 52 to 71.8µV in the right lower limb) and a decrease in VMO RMS for the right lower limb of G2NP (from 81 to 62.4µV) (Table 2). In the RMS 90º knee flexion angle, significant increase was observed in the VLO of the left lower limb (from 56.3 to 72.7µV) and in the VMO 90º for the right lower limb (from 85.9 to 120.5µV) of G1P. Interestingly, RMS of VMO 90º presented a group-time interaction, with higher values for G1P compared with the G2NP after the training period (G1P = 107.4µV and G2NP = 97.4µV) (Table 2).

- Median frequency (MF) at the 30º and 90º angles of knee flexion

In the MF, G1P presented a significant increase in VMO at 30º of knee flexion for both limbs (from 47 to 53.4Hz in the left lower limb and from 47.4 to 53.7Hz in the right lower limb). There was a decrease in MF of VLO at 30º of knee flexion in the right limb (from 59.5 to 49.8Hz) for G1P. Additionally, there was a significant decrease in MF of VLO at 30º of knee flexion in the right limb (from 58.6 to 51.1Hz) and in RF at 30º of knee flexion in the left limb (from 68.8 to 65.1Hz) for G2NP.

An increase in MF at 90º of knee flexion in the VMO was also observed for both limbs (from 44.2 to 48.8Hz in the left lower limb and from 45.5 to 51.1Hz in the right lower limb) for G1P (Table 3).

- Lower limb power (Jump test)

Lower limb Power increased in G1P in all evaluations (T2, T3 and T4) compared with T1, from 12.35cm to 12.41cm, 13.25cm and 14.35cm, respectively. On the other hand, G2NP did not increase lower limb power during the training (Table 4).

| Table 1 - Individual description of training sessions applied in each mesocycle |
|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|
| A | B | C | D | E | F | G | H |
| OG-2 | OG-2 | OG-1 | OG-1 | OG-1 | OG-1 | OG-1 | OG-1 |
| FMI 1 | FMI 2 | FMI 1 | FMI 1 | FMI 1 | FMI 1 | FMI 1 | FMI 1 |
| FMS 1 | FMS 2 | FMI 1 | FMI 1 | FMI 1 | FMI 1 | FMI 1 | FMI 1 |
| FMI 1 | FMI 2 | FMI 1 | FMI 1 | FMI 1 | FMI 1 | FMI 1 | FMI 1 |
| FMS 1 | FMS 2 | FMI 1 | FMI 1 | FMI 1 | FMI 1 | FMI 1 | FMI 1 |
| OG-2 | OG-2 | FMS 1 | FMS 1 | FMS 1 | FMS 1 | FMS 1 | FMS 1 |

OG-1 – Frontal movement/Lateral movement
OG-2 - Stretching.
FMI 1 – Hip abduction /Hip adduction/Calf raise/Hip flexion/Knee flexion/Hip flexion with knee extension/Hip extension/Lunges (Static).
FMI 2 – Wide half squat/Lunges (with frontal movements)/Calf extension/Half squat followed by jump/Lateral and frontal jumps (plyometrics/Trunk flexion /Knee flexion/Hip extension.
FMS 1- Forearm flexion/forearm extension/Shoulder press alternated chest/back/Lateral raise/Lateral raise with front inclined trunk/Frontal raise/Horizontal rows/Upright deltoid rows.
FMS 2 – Medicine ball throwing (chest)/(overhead)/(hip/front)/(hip/back)/Medicine ball throwing overhead/back/Alternated right/left/Arm curl/ln doubles (front medicine ball throwing).
Table 2 - Root mean square (RMS) in the maximal voluntary isometric contraction (MIVC) of the knee extension at 30° and 90° for the right lower limb (RLL) and the left lower limb (LLL) in the periodized group (G1P) and nonperiodized (G2NP).

The values were expressed by mean ± standard deviation of the mean (SD) (p ≤ 0.05). (A) Statistically significant intra-group difference compared with T1; (a) Statistically significant difference between the variables (T4 – T1) Vastus medialis oblique (VMO), vastus lateralis longus (VLL), vastus lateralis oblique (VMO) and rectus femoris (RF) muscles. Evaluation before the training program (T1) and after three months of training (T4).

Table 3 - Median frequency (MF) in the maximal voluntary isometric contraction (MIVC) of the knee extension at 30° and 90°, for the right lower limb (RLL) and the left lower limb (LLL) in the periodized group (G1P) and nonperiodized (G2NP).

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Table 4 - Results of the Jump Test for the periodized group periodized (G1P) and nonperiodized (G2NP) in the different evaluations of the strength training.

The values were expressed by mean ± standard deviation of the mean (SD) (p ≤ 0.05). (A) Statistically significant intra-group difference in relation with T1 (A) Statistically significant difference between the variables (T4 – T1). Evaluations before the training program initiation (T1), after four weeks (T2), eight weeks (T3) and after three months of training (T4).
DISCUSSION

The results of the present study showed significant increase in electromyographic activity of the muscle groups evaluated in response to a home-based periodized strength training, so that a possible equilibrium between VMO and VLO was induced, which is considered an important factor for knee joint stability (WILKERSON et al., 2004). The synchronism between VMO and VLO provide the correct positioning of the patella, allowing harmonious sliding during knee flexion and extension (WILKERSON et al., 2004).

Knight and Kamen (2001) compared the muscle activation during maximum voluntary isometric contraction (MIVC) of the knee extensors in young (18-29 years old) and elderly women (67-81 years old) after six weeks of strength training performed three times per week with 85% of 1RM. The authors concluded that the elderly were 30% weaker than young women during the study. The strength increase was 30% for the elderly and 36% for the young. However, the small differences observed in the muscle activation were not a limiting factor associated with aging, with regard to the development of knee extensor strength. Similarly, in the present study there was a significant increase in electromyographic activity of the knee extension muscles in elderly women. Patten and Kamen (2000) evaluated young and elderly participants of a strength training program for six weeks performed two times per week. After the training both groups showed significant increase in strength (44% for young and 48% for elderly). The authors commented that this adaptation in strength is highly dependent on a decrease in the co-activation of the antagonists.

With regard to median frequency (MF), the volunteers in G1P showed an increase in VMO at 30° of knee flexion for both limbs; this pattern was not observed in the nonperiodized group. In the results at 90° of knee flexion significant increase in MF of VMO 90° was observed for both limbs in G1P. Furthermore, periodization was shown to be efficient in increasing MF of VMO at 90° compared with the nonperiodized training results. The aim of periodization includes maximizing the overload principle and allowing a better relationship between stress/recovery. Strength training periodization is a relevant tool in designing an exercise program for regular strength training practitioners and the variation of training components in a more frequent pattern may induce greater increase in strength and electromyographic activity (RHEA et al., 2002).

In this sense, Solomonow et al. (1990) suggested MF as a score to identify the control in the recruitment of several muscles, accompanied by the increase in contraction force. This concept can justify the intra-group MF pattern at the 30° angle, which was slightly higher when compared with 90° angle. This small difference may have occurred because at the 30° angle, the muscle length of the knee extensors is at a mechanical disadvantage, so that the firing rate of the motor units is increased at this angle (SOLOMONOW et al., 1990).

Corroborating the results of the present study, Knight and Kamen (2001) found increased MF after strength training performed three times per week in young (mean age of 24 years) and elderly women (mean age of 72 years). The authors also observed a reduced susceptibility to fatigue of knee extensor muscles after the training period.

Another important variable that was measured was the lower limb power, since the decrease of this variable is very significant in aging, which impair the strength of the knee extensors. These negative alterations severely limit the performance of basic daily activities (KALAPOTHARAKOS et al., 2005). Hunter and Marshall (2002) proposed that muscle power training increases the use of elastic energy by muscles and inhibits the golgi tendon organ to facilitate the development of strength in a specific muscle group.
Martel et al. (2005) evaluated the effects of plyometric training on the jump height and strength of lower limbs in volleyball players. The authors found a significant increase in vertical jump after six weeks of training. Similar to the results of the present study, Roelants et al. (2004) found an increase in muscle power of knee extensors, movement velocity and countermovement jump after strength training with loads of 20RM in 58-74 year-old women. The number of repetitions (20RM) was similar to that used in the present study.

Häkkinen et al. (2001) evaluated lower limb power in post-menopausal women with and without fibromyalgia that were submitted to a 21 weeks training program, starting with 15-20 repetitions and a load of 40-60% of 1RM, followed by 10-12 repetitions with 60-70% of 1RM. The elderly with fibromyalgia obtained a significant strength gain of 10%, while healthy elderly gained 13% in the vertical jump. Thus, it is important to emphasize that training specificity was an important factor for the results found in the present study, so that there was a strict relationship between the movements performed in the training sessions and the jump test.

The increase in RMS and MF observed in the elderly after strength training can reduce the probability of muscle imbalance, injuries and patello-femoral dysfunction. Another important factor is that the higher losses in strength and muscle mass are observed in lower limbs in the elderly (VANDERVOOT, 2002). Nevertheless, the increase in lower limb electromyographic activity and power observed in the present study has clinical significance in aging.

In summary, home-based strength training periodization induced better results in lower limb neuromuscular variables compared with nonperiodized training in elderly women. These results are very important and have daily practical application, showing the responses to periodized strength training and its benefits in older women. Therefore, this study can provide parameters for training prescription to increase lower limb strength in aging persons. Finally, the proposed training can be developed in several places, without the necessity of specific weight training machines and apparatuses, providing an interesting tool for low cost health promotion programs in gerontology.

REFERENCES


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