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Age responses to exercise training in older adults

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Abstract

Purpose: The purpose of the present study was to evaluate how age affects the responses on body composition, strength and dynamic balance to a 32-week multicomponent training in older adults.

Methods: 126 subjects were stratified in two age groups, the young-old group (YO, 60 – 70 years old) and the old group (O, ≥71 years old) and were randomly assigned to an exercise (EG) and a control group (CG). The EG completed a 32-week progressive multicomponent training (3 sessions of 50 minutes per week). Body composition, isokinetic lower limb strength, and agility / dynamic balance were assessed before and after training. Three-way ANOVA with repeated measures was used to determine trial (baseline, 32 weeks), training group (control, exercise) and age group (YO, O) effects on the variables.

Results: No group differences were observed in baseline values, with the exception of the 8 foot Up and Go (UG) and trunk fat mass (FM). After the 32 weeks, the YOEG decreased appendicular (11.84 ± 2.87 to 11.42 ± 2.75 kg), total FM (25.85 ± 6.50 to 25.05 ± 6.41 kg), improved total fat-free mass (42.25 ± 8.82 to 42.61 ± 8.89 kg) and right knee extension peak torque (140.00 ± 42.50 to 149.53 ± 42.44 %). Both YOEG and OEG showed a significant improvement in UG test score, and increased appendicular lean mass and knee flexion peak torque. The OCG increased the trunk FM (9.91 ± 3.88 to 10.52 ± 3.52 kg) and decreased total BMC (19.21 ± 4.83 to 18.73 ± 4.84 kg) and BMD (1.03 ± 0.14 to 1.01 ± 0.14 g cm^{-2}) after 32 weeks.

Conclusion: This study showed that 32 weeks of multicomponent training can produce significant changes in dynamic balance and in body composition- and strength-related variables and the rate of response was influenced by age, as the YOEG showed higher and better adaptations compared to the OEG.

Key words

Aging, Elderly, Exercise training, Body composition, Muscle strength, Physical function

Introduction

The demographics of world are set to change, with more elderly living in developing countries. The World Health Organization (WHO) points out that the percentage of the world population aged 60 years and over will double (11% - 22%), from 2000 to 2050 (WHO 2012). In the same period, it is likely that the total number of people over 60 years old will increase from 605 million to 2 billion (WHO 2012). This growth is more evident in people in their eighties, whose number is expected to have almost quadrupled to 395 million (WHO 2012). In fact, the U.S. Census Bureau states that life expectancy at birth overcomes 80 years old in 11 countries (Kinsella and He 2009). Although this numbers of increased longevity confirm the success of improved global heath, they pose many challenges (Kinsella and He 2009). In particular, from a public heath point of view, delaying physical frailty is of great importance and one of the major goals of heath providers and gerontology researchers (Rikly and Jones 1999).

Aging is associated with important changes in muscle strength, body composition and physical function (Witham and Avenell 2010; Doherty 2003; Baumgartner et al. 1995). It is well established that muscle strength declines as age increases after the 30 decade (Doherty 2003). Studies have revealed that it reaches a peak value at around the third decade, followed by a steady state and a decline after age 50 (Lindle et al. 1997; Hurley 1995; Lauretani et al. 2003). Lang et al. (2010) reviewed the findings of cross-sectional studies comparing young (20-40 years) and old (70-80 years) healthy adults and describes declines of 20 to 40% in the maximum knee extensor (torque in the elderly. Superior losses, of at least 50%, occurred for those in their eighties (Doherty 2003). Furthermore, this age-related decline was maintained when elderly subjects of different ages (60-79 and over 80 years old) were compared, having the older group showed a reduction of 15% in muscle strength (Ko et al. 2012). Also, a longitudinal study reported that 10 years after the first evaluation, subjects showed a decline in isokinetic strength of knee extensors and flexors of respectively, 14% and 16% per decade for both genders (Hughes et al. 2001).

Moreover, body composition changes occur over aging (Baumgartner et al. 1995). There is a progressive rise in fat mass (FM) and decrease of fat-free mass (FFM) from the age of 20 to 70 years; afterwards both follow a decreasing trend (Mathus-Vliegen 2012; Kyle et al. 2001; Johannsen et al. 2008). The distribution of FM and FFM is modified to a central pattern, with the reduction of the peripheral mass (Mathus-Vliegen 2012). Lower limb muscle mass undergoes a steady decline with onset at 45 years old (Janssen et al. 2000; Kyle et al. 2001). There is also a decrease in the amount of bone tissue with aging, which results in bone weakness and increased risk of fractures (Marques et al. 2012).

Indeed, studies demonstrate that lower limb muscle strength, FM and LM influence the walking performance of elderly people (Marques et al. 2011a; Visser et al. 2005). Muscle mass and strength loss are regarded as one of the main factors that contribute to disability, loss of mobility and falls in older people (Lauretani et al. 2003; Lang et al. 2010; Baumgartner et al. 1998). It was observed that men and women in the eighth decade of life that are in the lowest quartile of knee extension muscle strength were 2.64 and 2.15 times more prone to develop mobility limitations compared to those in the highest quartile (Visser et al. 2005). Actually, around the eighties, strength level often reaches a level below the necessary to perform everyday activities (Rikli 2000) and a sedentary lifestyle is thought to play an important role (Janssen et al. 2000; Doherty 2003; Vandervoort 2002).

It is recognized that physical activity has positive influences on maintaining older people functional capacities, on the reduction of the age-related disease risk and on the enhancing of daily quality of life (Stewart 2005; Chodzko-Zajko et al. 2009; Baker et al. 2009; Cress et al. 1999; Paterson and Warburton 2010; Carvalho et al. 2009). The American College of Sports Medicine recommends a multicomponent training program, with aerobic, strength and flexibility exercises, in order to improve and maintain physical function in older adults (Chodzko-Zajko et al. 2009). The positive adaptation on bone density, muscle mass, muscle strength, functional fitness and weight loss of this combined training programs have been reported (Mathus-Vliegen 2012; Carvalho et al. 2009; Marques et al. 2011b; Marques et al. 2012). Also, it has been shown that multicomponent training programs produce improvements on functional fitness of older adults of different ages (Puggaard 2003; Toraman and Sahin 2004). However, although it is recommended to maintain physical activity throughout life, it is known that people become more sedentary with aging (Johannsen et al. 2008; Corder et al. 2009).

With the increasing of the population's lifespan and the knowledge of the importance of physical activity in later years, it is important to identify effective programs for older adults. However, little information is available about the optimum prescriptions for different age populations (Rikli 2000; Washburn 2000; Hughes et al. 2011; Rikli and Jones 2012). Therefore, the main purpose of this study was to evaluate how age affects the responses of body composition, isokinetic lower limb strength, and agility/ dynamic balance, to a 32 weeks multicomponent training program, analyzing different age groups (young old, YO – 60 - 70 years old and old, O – ≥71 years old).

Materials and Methods

Participants and experimental design

Participants were recruited through advertisements in the Porto area newspapers for participation in this university-based study. The eligible participants pool were restricted to older adults with the following characteristics: aged ≥ 60 years, white, community-dwelling status, not engaged in structured exercise training programs, free of hormone therapy use for at least 2 years, lack of use of any medication and nutritional supplements known to affect bone metabolism (such as diuretics, corticosteroids, anticonvulsants, immunosuppressive medications, non-steroidal anti-inflammatory drugs, asthma medications with corticosteroids, vitamin D, and calcium), and lack of diagnosed or self-reported cardiovascular, pulmonary, metabolic, renal, hepatic or orthopedic medical conditions.

On the initial screening visit, a total of 139 volunteers (mean age 69.2 ± 5.7) received a complete explanation of the purpose, risks, and procedures of the investigation. After signing a written consent form, the past medical history and current medications of the participants were determined. Eight subjects were excluded due to medical reasons (three used medication known to affect bone metabolism and five had musculoskeletal disorders that contra-indicate participation in exercise testing) and five were excluded due to current involvement in water-based exercise activities. Eligible participants were stratified by their age group. There were 83 subjects in the YO group (between 60 – 70 years) and 43 subjects in the O group (between 71 – 83 years).

Participants' characteristics are listed in Table 1. This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human participants were approved by the institutional Review Board.

Measurements

The same evaluator on each test, at the faculty facilities, performed all measurements. All test stations were organized in a circuit and the same conditions were maintained for each test.

Bone and Body Composition

Dual-energy X-ray absorptiometry (DXA; QDR 4500A; Hologic, Bedford, MA) was used to measure total bone mineral content (BMC, kg), total bone mineral density (BMD, g cm^{-2}), total lean mass (LM, kg), fat mass (FM, kg), and FM (%) through whole-body scans as described previously (Marques et al. 2011b). Appendicular skeletal LM and FM were generated as the sum of LM and FM in arms and legs and were determined by the region of interest (ROI) program.

Height and body mass were recorded using a portable stadiometer and balance weighing scales, respectively. BMI was calculated as body mass (kilograms) divided by height (meters) squared and categorized according to established cut points of <25, 25–30, and ≥30 (WHO 2000); obesity was considered as BMI ≥30 kg m^{-2}.

Muscle strength

The dynamic concentric muscle strength of the right lower limb, namely knee flexion (KF) and extension (KE) muscle groups, was measured on an isokinetic dynamometer (Biodex System 4 Pro; Biodex, Shirley, NY). Strength measurements were carried out in accordance with the manufacturer's instructions for KE/KF at 60 s^{-1} (1.05 rad s^{-1}) as described elsewhere (Marques et al. 2011b). Peak torque, represented as a percentage normalized to body weight, was used for the statistical analyses. The coefficient of variation was 5.1% and 5.5% for KE and KF repeat measurements, respectively (conducted with the same machine by the same examiners).

Agility/dynamic balance

Agility/dynamic balance was measured using the 8-foot Up and Go (UG) test. The score corresponds to the shortest time to rise from a seated position, walk 2.44 m (8 foot), turn, and return to the seated position, measured to the nearest one-tenth of a second.

Exercise intervention

The exercise training group completed a 32-week progressive multicomponent training consisting of three sessions per week (non-consecutive days). Each exercise session lasted approximately 50 minutes. Training workouts consisted of a five-minute warm-up that included stretching, warm-up exercises, 25 minutes of aerobic exercise that mainly consisted of walking but also included stepping and dancing, 15 minutes of muscular endurance exercises performed concentrically and eccentrically, involving squats, hip flexors, extensors, and abductors; knee flexors and extensors and upper body exercises performed using elastic bands and dumbbells; and a 5-minute cool-down. In the first month, the intensity of the aerobic exercises was gradually increased from 50-60% to 70-80% of the $HR_{Reserve}$, where a subject´s maximum heart rate (i.e. HR_{max} = 208 – 0.7 age) was calculated as suggested by (Tanaka et al. 2001) or from a rating of perceived exertion (RPE) of 4-6 to 7-8. In order to make sure that the subjects were exercising at the targeted intensity, Polar Heart Rate Monitors (Polar Team System, Finland) were worn during each exercise session. For strength exercises repetitions were increased from eight to 15 and the number of sets increased to three; the working load also increased to achieve the target intensity of 7-8 on the RPE scale. When an individual RPE was under the rating of seven for two consecutive sessions, the subject was instructed to increase the load so that he/she could perform two sets of 12-15 reps at an appropriate RPE. Each session was led by two research assistants and supervised by the coordinator and senior researcher.

Statistical analysis

All data are reported in means ± SD. Statistical analyses were performed using SPSS (version 20.0; SPSS, Inc. Chicago, IL). Descriptive statistics were computed for the dependent variables. Independent sample T-test was used to compare training age groups at baseline variables. Three-way ANOVA with repeated measures were used to determine exercise group (EG, CG), age group (YO, O), and trial (baseline, 32 weeks) effects on agility, and muscle strength-, bone-, body composition-related variables. When ANOVA revealed significant interaction (trial x group, trial x age, trial x age x group), Bonferroni post hoc tests were performed to determine differences between initial and final values in each group.

Results

All the 126 participants completed the 32 weeks of the study, having the 63 participants in the exercise group performed 96 sessions of training (maximum attendance). No exercise or assessment-related adverse effects were reported.

The characteristics of the study participants are listed in Table 1. Regarding obesity classification, the higher proportion of participants was overweight (BMI between 25 and 30 kg m^{-2}). A significant difference of age between the YO and the O groups was confirmed. However, the average age of YO groups (exercise vs control), as well as O groups (exercise vs control) did not differ significantly. The YO group and O group did not present any other significant differences, with the exception of the percentage of female subjects, which was higher in the YO group.

Also, at baseline, no significant differences were identified among the groups in the tests performed, with the exception of the UG test and trunk FM. The YOEG was faster than the YOCG in the UG ($p < 0.001$), whereas the OEG had higher trunk FM than the OCG ($p = 0.033$).

Bone and Body Composition

Significant age x group x time interactions were found on total BMC ($p = 0.002$) and BMD ($p = 0.002$), as show in table 2. Indeed, different responses were noticed in the different groups over time. Also, it should be highlighted that both total BMC ($p < 0.001$) and BMD ($p < 0.001$) results decreased significantly with time in the OCG, while the YOCG did not show significant changes.

On all variables of FM measured there were significant group x time interactions ($p = 0.006$ for appendicular FM, $p = 0.003$ for trunk FM and $p < 0.001$ for total FM) and age main effects ($p = 0.046$ for appendicular FM, $p = 0.015$ for trunk FM and $p = 0.023$ for total FM). The YOEG group showed a significant reduction of appendicular and total FM ($p < 0.001$), whereas the OCG significantly increased trunk FM ($p = 0.034$).

A significant age x group x time interaction was found on appendicular LM ($p = 0.024$). Both YOEG ($p = 0.011$) and OEG ($p < 0.001$) showed a significant improvement on the LM content, but no significant modifications were observed on the control groups.

For total FFM, a significant group x training interaction was found ($p = 0.029$). Only the YOEG showed a significant increase in the results after the training ($p = 0.040$). No significant interactions or main effects were observed on trunk FFM, total FM and BMI.

Muscle strength

The results of maximal KF and KE torques at 60° s^{-1} for the right lower limb and the adjustment for body weight are shown in table 3. There were significant group x time interactions on KF torque of the right leg at 60° s^{-1} ($p < 0.001$). Accordingly, different responses were observed in the exercise and in the control groups over time, particularly significant increases in both YOEG ($p < 0.001$) and OEG ($p = 0.047$), in contrast with non-significant decreases of YOCG and OCG. Both group ($p = 0.034$) and age ($p = 0.045$) main effects were observed on KF torque adjusted to body weight. Also, a significant time main effect was found on KE torque adjusted to body weight ($p = 0.019$). KE torque adjusted to body weight ($p = 0.024$) showed improvements with training in the YO group. Moreover, neither YOCG nor OCG demonstrated any significant changes in all strength tests following the 32 weeks period.

Agility/dynamic balance

Significant group x training interactions were found of the UG test ($p < 0.001$), as listed on table 4. Only the exercise groups significantly decreased the time of performance after the 32 weeks ($p < 0.001$ for both). The post-training results of the YOEG and OEG were significantly shorter than the control groups ($p < 0.001$ for both). Also, there was a significant main effect of age ($p < 0.001$).

Discussion

This study aimed to understand how age interferes with the response to a multicomponent training program on body composition, isokinetic lower limb strength, agility and dynamic balance. The results confirmed that there are differences in the outcomes after training for subjects in the 60-70 years old range when compared to over 70 years old. The YOEG showed a decrease in the appendicular and total FM and an improvement of total FFM and KE peak torque, whereas no significant changes were observed in the OEG. However, there were variables in which age seem to have less interference, such as the UG test, appendicular LM and KF peak torque, since both YOEG and OEG showed significant increases. Another important finding was the gain of trunk FM and decrease of total BMC and BMD seen on OCG after the 32 weeks of the study.

Previous studies have related the role of endurance training on FM reduction among the elderly (Solberg et al. 2011; Strasser et al. 2009; Mathus-Vliegen 2012), but no data about the age influence could be found. The results show that the training program led to a decrease of appendicular and total FM of the YOEG. It could be hypothesized that the 32 weeks of the study were not sufficient to show significant effects on O participants. The age-associated reduction of metabolism and endocrine changes that favor the obese state are more evident as aging occurs (Witham and Avenell 2010). Moreover, the lack of a marked endurance component of the training and the absence of a nutritional intervention seem to have compromised a greater effect in both age groups. It has shown that the combination of diet and exercise is more effective than exercise alone in the FM reduction of older adults (Villareal et al. 2011; Witham and Avenell 2010). Also, the addition of physical activity is thought to decrease the skeletal muscle fat infiltration that occurs with aging, consequently improving muscle quality (Witham and Avenell 2010), which corroborates the present results of a reduction of appendicular FM. However, although it is recognized that a high FM is related to an increased risk of disabilities (Visser et al. 1998), there is evidence that appendicular FM can exhibit an independent protective effect on BMD, so reductions should be managed carefully.

Lower limb muscle strength is one of the most important determinants of good physical performance in old adults (Lauretani et al. 2003; Fried and Guralnik 1997). The results showed that only the YOEG improved KE muscle strength, but both age groups were able to improve KF. Although there is previous evidence that strength training could increase muscle strength in nonagenarians (Fiatarone et al. 1990), in this study, age effect seems to be important on the KE outcome, which might be related to different levels of intensity and duration of the training program. In fact, the comparison of different types of exercise revealed that strength training is the most effective in producing muscle strength increases in elderly (Solberg et al. 2011;

Volkers et al. 2012). These results might also be linked to the loss of appendicular FM observed in the YOEG, as described above, since one important morphologic aspect of the muscle aging is the infiltration of lipids within the fibers (Lang et al. 2010).

Other important findings of the present study were the significant decreases of total BMC and BMD and the increase of trunk FM, as well as the trend to decrease KE muscle strength values, seen on OCG, after the 32 weeks of the study. Regarding bone mass, these findings are in accordance with previous data which documented that age is an important predictor of BMD in older adults (Marques et al. 2012). Although it has been reported that osteogenic responsiveness to mechanical loading declines with age (Lanyon and Skerry 2001), the present results seem to show that exercise counterbalanced the age-related declines, since in contrast to the OCG, the OEG tended to increase total BMC and maintained BMD outcomes. Concerning the trunk FM gain observed, it does not follow the previous reports pointing out that after the age of 70 years old, FM had a tendency to decrease (Mathus-Vliegen 2012). In spite of having significantly higher values of trunk FM at baseline, the OEG showed a downward trend, so once again it could be said that exercise has opposed the aging effects. Also, exercise demonstrated a tendency to counterbalance age effects on KE muscle strength, in agreement to the previous reports that highlighted the importance of physical activity throughout a person's lifetime (Volkers et al. 2012).

Although cross-sectional and longitudinal studies have shown differences through aging on body composition, bone mass, muscle strength and functional fitness, there is a gap in the literature regarding the effects of exercise in old adults through decades. As far as we know, only Toraman and Sahin (2004) have evaluated the effects of a multicomponent training on men and women of two different age groups' functional fitness. They found out significant increases in all the tests used in both young and older subjects of the training group, as well as better outcomes in exercise subjects than the ones in the control group with the same age. However, the responses to training were similar in both age groups. This was not observed for the majority of the variables measured in the current study. One possible reason for this difference is the fact functional fitness tests are more likely to be influenced by repetition than DXA and Biodex assessments, so the post-training results of Toraman and Sahin (2004) could have been increased partially by the subjects improved knowledge of the test. The results of the single functional fitness test used in the present study are in line with what was reported by Toraman and Sahin (2004), since it was demonstrated that both exercise groups were able to improve the performance in the UG test. This test evaluates the integration of power, speed, agility and dynamic balance, reflects activities of the everyday life, such as getting up quickly to answer the door and is also a good predictor of recurrent falling (Rikly and Jones 1999). Thus, it could be said that the multicomponent training showed a positive effect on the improvement of the physical capacities required to an independent living and also counterbalanced the aging-related declines. Also, the results were consistent with previous findings that agility and dynamic balance of older adults can be improved by multicomponent training (Nelson et al. 2004; Carvalho et al. 2009), but the current results add that not only the 60-70 old adults but also the ones over 70 years old can improve these parameters.

It has been suggested that exercise programs for the elderly were more beneficial to the people with a lower function at baseline, given that greater improvements were observed after the training period, whereas little advantages were achieved by older adults with an initial high function (Solberg et al. 2011; Meuleman et al. 2000). However, this study showed that improvements occurred mostly in the YOEG, which had better results in the majority of the variables measured at baseline and at the end of the study. So it might be proposed that other factors can contribute to the more effectiveness of the training, such as younger age. The same study reported positive influences on body composition and muscle strength after training programs of three types, namely traditional and functional strength trainings and endurance training (Solberg et al. 2011). Thus, further studies concerning the most effective training program for older people in different decades should be conducted. The oldest subjects are of special concern, as the age-related frailty makes them more prone to injuries and so exercises need to be better adapted to the physiologic aging process.

Attention should also be paid to the reasons for the low rate of older people that enroll training programs, but even more to the small amount of moderate physical activity performed in daily life, as people in their nineties are thought to spend 96 % of the day in sedentary or low intensity activities (Johannsen et al. 2008). Advice from health professionals and the development of simple, safe and attractive local programs are an important part of the solution.

Finally, this study has some limitations that should be comment. There are other factors that can influence the response to training besides age, such as nutrition, genetics, motivation, previous physical activity. No gender division was performed, but a recent meta-analysis related that men and women do not seem to differ in the relation between physical activity and muscle strength (Volkers et al. 2012). In addition, the percentage of female participants was higher in the YO than in the O group, in contrast with the described increase of women proportion with age in the older population (Kinsella and He 2009). In addition, the small sample size (especially in the O groups) and the health status of the subjects may not allow this study to be extended to all older adults, with different comorbilities.

Conclusions

In summary, this study showed that the response to the 32 weeks of multicomponent training was influenced by age. Only the YOEG showed significant changes in the appendicular and total FM, total FFM and KE peak torque after the exercise. It was also demonstrated losses in bone mass and muscle strength, as well as an increase of trunk FM during the 32 weeks of the study only in the OCG (≥71 years old), which may have been counterbalanced by the exercise program.

This study strengthens the idea that physical activity needs to be adapted to the physiologic ageing process, as it can effectively contribute to the goal of preserving a good quality of life until later years. The understanding of the responses to exercise will help to design individualized training programs to prevent disability and loss of independence. Further studies with older people of different ages need to be performed.

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Conflict of interests

The authors declare that they have no conflict of interest.

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Tables

Table 1 Baseline characteristics of the study subjects (mean ± standard deviation)

Variable	Total sample (n = 126)	Young Old Group (n = 83)	Old group (n = 43)
Age (years)	68.90 ± 5.82	65.34 ± 2.89	75.77 ± 3.36*
Gender - female (n / %)	97 / 77	69 / 83.1	28 / 65.1*
Height (m)	1.56 ± 0.08	1.56 ± 0.09	1.57 ± 8.43
Weight (kg)	67.79 ± 11.27	68.48 ± 11.58	66.47 ± 10.67
BMI (kg m^{-2})	27.76 ± 3.78	28.18 ± 3.76	26.96 ± 3.73
Obesity classification (n/ %)			
Normal weight	31/ 24.6	17/ 20.5	14/ 32.6
Overweight	59/ 46.8	41/49.4	18/ 41.9
Obese	36/ 28.6	25/ 30.1	11/ 25.6

* Significantly different from young old group.

Table 2 Pre- and post-training results (mean ± standard deviation) of body composition

	Exercise group (*n* = 63)				Control group (*n* = 63)										
	Young old group (n = 42)		Old group (n = 21)		Young old group (n = 41)		Old group (n = 22)								
Variables	Pre-training	Post-training	Pre-training	Post-training	Pre-training	Post-training	Pre-training	Post-training	*P* (group)	*P* (age)	*P* (time)	*P* (G x T)	*P* (G x A)	*P* (A x T)	*P* (A x G x T)
BMI (kg m^{-2})	28.06 ± 4.18	27.25 ± 5.44*	27.75 ± 3.71	27.75 ± 3.65	28.29 ± 3.33	28.36 ± 3.23	26.20 ± 3.66	26.30 ± 3.69	0.563	0.169	0.471	0.284	0.132	0.357	0.401
BMC total (kg)	18.06 ± 3.65	18.06 ± 3.70	18.28 ± 3.66	18.45 ± 3.56	18.07 ± 3.72	18.10 ± 3.62	19.21 ± 4.83	18.73 ± 4.84*	0.667	0.416	0.193	0.004	0.691	0.111	0.002
BMD total (g cm^{-2})	1.03 ± 0.09	1.02 ± 0.09	1.02 ± 0.11	1.02 ± 0.10	1.02 ± 0.10	1.02 ± 0.10	1.03 ± 0.14	1.01 ± 0.14*	0.866	0.964	0.044	0.050	0.981	0.151	0.002
Appendicular FM (kg)	11.84 ± 2.87	11.42 ± 2.75*	11.05 ± 2.99	10.91 ± 3.08	12.25 ± 2.66	12.22 ± 2.73	10.63 ± 3.30	10.77 ± 3.29	0.764	0.046	0.075	0.006	0.420	0.067	0.635
Trunk FM (kg)	13.05 ± 3.99	12.66 ± 4.01	12.40 ± 3.75	11.99 ± 3.64	12.94 ± 3.55	13.05 ± 3.61	9.91 ± 3.88[c]	10.52 ± 3.52*	0.189	0.015	0.873	0.003	0.129	0.334	0.304
Total FM (kg)	25.85 ± 6.50	25.05 ± 6.41*	24.41 ± 5.87	23.94 ± 6.09	26.17 ± 5.81	26.24 ± 5.92	22.06 ± 6.03	22.38 ± 6.20	0.601	0.023	0.084	0.001	0.240	0.255	0.876
Appendicular LM (kg)	16.80 ± 4.14	17.05 ± 4.26*	16.74 ± 3.57	17.26 ± 3.54*	16.97 ± 4.22	16.99 ± 3.94	17.48 ± 3.52	17.23 ± 3.57	0.783	0.762	0.025	<0.001	0.839	0.966	0.024
Trunk LM (kg)	20.66 ± 4.21	20.73 ± 41.85	21.00 ± 4.00	20.90 ± 3.51	20.79 ± 3.98	20.77 ± 3.81	21.18 ± 4.38	21.12 ± 4.40	0.851	0.682	0.781	0.861	0.942	0.499	0.669
Total LM (kg)	40.44 ± 8.52	40.83 ± 8.55	40.80 ± 7.43	40.72 ± 8.64	40.87 ± 8.36	40.85 ± 7.90	41.95 ± 8.36	41.88 ± 8.62	0.659	0.705	0.702	0.493	0.766	0.363	0.456
Trunk FFM (kg)	21.10 ± 4.29	21.19 ± 4.28	21.44 ± 4.07	21.34 ± 3.58	21.23 ± 4.05	21.23 ± 3.87	21.62 ± 4.46	21.55 ± 4.48	0.856	0.698	0.832	0.891	0.945	0.401	0.704
Total FFM (kg)	42.25 ± 8.82	42.61 ± 8.89*	42.63 ± 7.72	43.12 ± 7.56	42.65 ± 8.64	42.66 ± 8.13	43.87 ± 8.71	43.76 ± 8.98	0.716	0.615	0.078	0.029	0.824	0.991	0.566
Total FM (%)	37.61 ± 6.67	46.44 ± 62.92	36.36 ± 6.06	35.58 ± 6.17	38.05 ± 6.33	38.03 ± 6.29	33.43 ± 7.03	33.82 ± 7.51	0.390	0.157	0.531	0.568	0.824	0.494	0.457

G - group, A- age, T - training, BMI - body mass index, BMC - bone mineral content, BMD - bone mineral density, FM - fat mass, LM - lean mass, FFM - fat-free mass.

[c] Significant difference between pre-training OEG and OCG.
* Post-training value significantly different from the initial value (pre training) in the same group.

Table 3 Pre- and post-training results (mean ± standard deviation) of lower limb muscle strength

	Exercise group (*n* = 63)				Control group (n = 63)										
	Young old group (n = 42)		Old group (n = 21)		Young old group (n = 41)		Old group (n = 22)								
Variable	Pre-training	Post-training	Pre-training	Post-training	Pre-training	Post-training	Pre-training	Post-training	*P* (group)	*P* (age)	*P* (time)	*P* (G x T)	*P* (G x A)	*P* (A x T)	*P* (A x G x T)
KE PT R (N.m)	94.32 ± 32.63	100.31 ± 33.55*	90.56 ± 27.99	92.20 ± 27.12	88.49 ± 40.52	88.03 ± 36.79	76.24 ± 23.80	82.26 ± 19.68	0.073	0.205	0.071	0.775	0.794	0.770	0.138
KE PT/BW R (%)	140.00 ± 42.50	149.53 ± 42.44*	128.70 ± 41.30	138.14 ± 35.95	129.92 ± 44.71	131.15 ± 43.47b	117.46 ± 34.89	121.32 ± 28.43	0.053	0.123	0.019	0.174	0.989	0.803	0.789
KF PT R (N.m)	49.27 ± 19.51	54.11 ± 18.82*	43.99 ± 18.60	47.43 ± 18.41*	45.95 ± 18.85	44.81 ± 18.39°	40.14 ± 18.54	37.48 ± 19.45	0.059	0.072	0.134	<0.001	0.932	0.328	0.963
KF PT/BW R (%)	73.53 ± 23.42	77.44 ± 26.02	65.10 ± 22.96	69.72 ± 23.73	65.81 ± 22.52	67.97 ± 27.79	59.56 ± 24.58	54.66 ± 26.16	0.034	0.045	0.335	0.062	0.847	0.292	0.198

G - group, A - age, T - training, KE - knee extension, KF - knee flexion, PT - peak torque, BW - body weight, R60 - right lower limb at 60° s^{-1}.

[b] Significant difference between post-training YOEG and YOCG groups.
* Post-training value significantly different from the initial value (pre-training) in the same group.

Table 4 Pre- and post-training results (mean ± standard deviation) of agility/dynamic balance

	Exercise group (*n* = 63)				Control group (*n* = 63)										
	Young old group (n = 42)		Old group (n = 21)		Young old group (n = 41)		Old group (n = 22)								
Variable	Pre-training	Post-training	Pre-training	Post-training	Pre-training	Post-training	Pre-training	Post-training	*P* (group)	*P* (age)	*P* (time)	*P* (G x T)	*P* (G x A)	*P* (A x T)	*P* (A x G x T)
8ft UG (s)	5.05 ± 0.64	4.61 ± 0.61*	5.96 ± 1.11	5.22 ± 0.85*	5.65 ± 0.79[a]	5.63 ± 0.91[b]	6.32 ± 0.96	6.22 ± 0.97[d]	<0.001	<0.001	<0.001	<0.001	0.657	0.057	0.306

G - group, A - age, T - training, 8 ft UG – 8 foot Up and Go test

[a] Significant difference between pre-training YOEG and YOCG.
[b] Significant difference between post-training YOEG and YOCG.
[d] Significant difference between post-training OEG and OCG.
* Post-training value significantly different from the initial value (pre-training) in the same group

ANEXO 1

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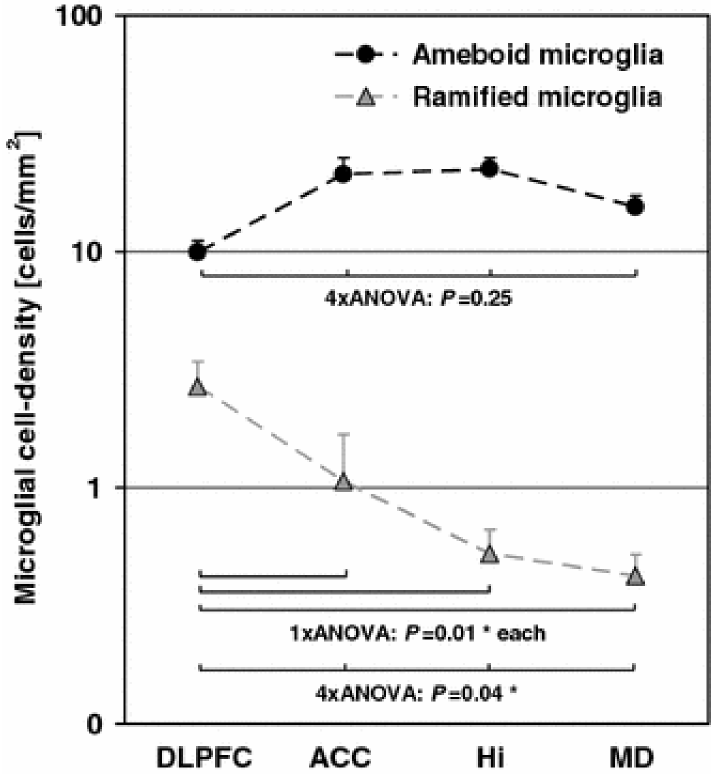

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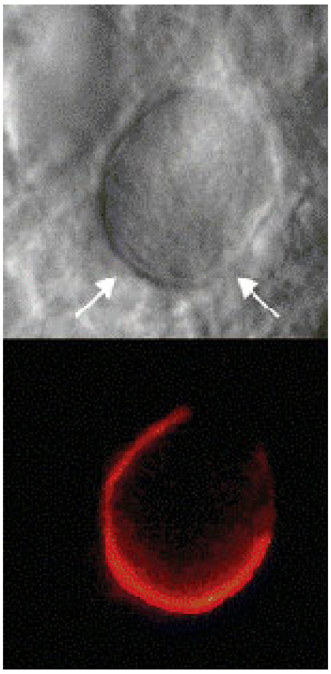

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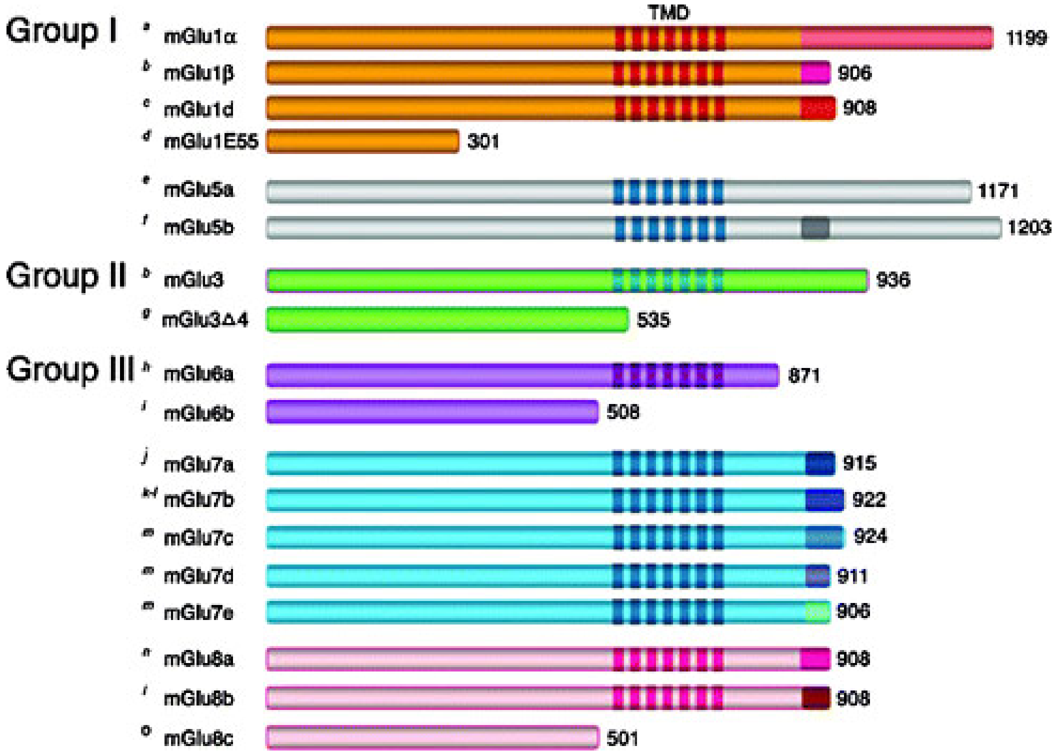

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