Static balance behavior along a deep water periodization in older men

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Summary

The aim of this study was to evaluate static balance along a deep water periodization in older men. Twenty-two older men (65.2±3.8 years) completed 16 weeks of training in deep water. In the first four weeks (weeks 1-4) low intensity training was conducted twice a week, emphasizing familiarization exercises with running technique in deep water and with aquatic environment. In the following weeks (weeks 5-16) an aerobic training of high intensity was performed three times a week, using only deep water running exercise. Static balance was assessed at week 0, 5 and 17 using an accelerometer in four positions: double- and single-legged stances with eyes open and eyes closed. Statistical analysis: We performed a repeat measures ANOVA with Bonferroni post-hoc (α=0.05). Static balance improved significantly after the first four weeks of training (week 1 to 4) in both single-legged stances (~33%) and double-legged stances (~54%) ($p<0.001$).Whereas after the high intensity training period (week 5 to 16) the values remained ($p>0.05$). The results showed an improvement in static balance throughout a deep water periodization. However, improvement is found after the first four weeks that were emphasized exercises of low intensity and familiarization with deep water running technique and with aquatic environment. Following, the high-intensity aerobic training was sufficient to keep these improvements.

Key words:
Exercise. Aging.
Postural balance.

Comportamiento del equilibrio estático a lo largo de una periodización de carrera en aguas profundas en hombres mayores

Resumen

El objetivo del estudio fue evaluar el equilibrio estático a lo largo de la periodización de carrera en aguas profundas en hombres mayores. Veintidós hombres mayores (65,2 ± 3,8 años) completaron 16 semanas de entrenamiento de carrera en aguas profundas. En las primeras cuatro semanas (semanas 1-4) el entrenamiento fue de baja intensidad y se realizó dos veces por semana. Los ejercicios fueron de familiarización con la técnica de carrera en aguas profundas y con el medio acuático. En las semanas siguientes (semana 5-16) se realizó un entrenamiento aeróbico de alta intensidad tres veces a la semana, usando solamente la carrera en agua profunda. El equilibrio estático fue evaluado en la semana 0, 5 y 17 utilizando un acelerómetro en cuatro posiciones: apoyo sobre ambos pies con los ojos abiertos y vendados y apoyo sobre un pie con los ojos abiertos y vendados. Análisis Estadístico: ANOVA para medidas repetidas con post hoc de Bonferroni (α=0,05). El equilibrio estático se ha mejorado significativamente después de las primeras cuatro semanas de entrenamiento (semanas 1-4) en las posiciones en apoyo en un solo pie (~33%) y en los apoyos en los dos pies (~54%) ($p<0,001$). Mientras después del período de entrenamiento de alta intensidad (semanas 5-16) los valores se mantuvieron ($p>0,05$). Los resultados mostraron una mejora en el equilibrio estático durante todas la periodización en aguas profundas. Sin embargo, la mejora se encuentra después de las primeras cuatro semanas de entrenamiento, en los que fueron realizados ejercicios de baja intensidad y la familiarización con la técnica de la carrera en agua profunda y con el medio acuático. Después, el entrenamiento aeróbico de alta intensidad fue suficiente para mantener estas mejoras.

Palabras clave:
Ejercicio. Envejecimiento.
Equilibrio postural.

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Introduction

Worldwide population aging is becoming increasingly important due to longer life expectancies and better health conditions of the population. According to projections by the World Health Organization[1], in 2050, older adults population will include 1.9 billion people and will represent one-fifth of world population. This aging trend raises an important issue for society because aging process involves significant structural and functional changes in the individual, thus increasing susceptibility to chronic degenerative diseases, falls and injuries[2].

Postural control system integrates sensory information from somatosensory, vestibular and visual systems. In addition, central nervous system uses mechanical components (strength and support base), cognitive processes (attention and learning), sensory and motion strategies, dynamic controls and orientation in space to maintain stable postural balance[3]. With aging, there is a decrease in function of motor, nervous, sensory and vestibular systems, and a decrease in reaction time, vision and proprioception[4,5]; all factors that directly interfere with balance.

Previous studies has shown that physical activity is significantly associated with static and dynamic balance in older adults and that a sedentary lifestyle negatively affects postural stability in older adults[6,7]. Biological factors associated with aging that impair physical abilities of older adults cannot be avoided. However, many studies have been conducted in this population to evaluate the magnitude of the effect that physical activity has on a lower decline and even a possible improvement in such components. A recent meta-analysis, including 54 randomized controlled trials, concluded that exercise is an important intervention that can prevent falls[8].

In this context, exercise in an aquatic environment has been strongly recommended for older adults[9-14] because it provides low impact on joints of lower limbs and spine[15] and reduced cardiovascular overload[16,17]. Among aquatic exercises, deep water running has gained attention in scientific literature. Deep water running is performed with aid of a float vest, which serves to keep the body in an upright position and to avoid contact of the feet with the bottom of the pool, thus eliminating any impact[18].

Moreover, these characteristics combined with the fact that deep water running is an exercise in an open kinetic chain makes it necessary to have a period of familiarization with the modality. In this period the participants are performed familiarization with aquatic environment, with use of float vest and deep water running technique. These exercises produce greater instability in postural control and a large variety of proprioceptor stimuli that may provide improvements in balance. After this period, it may be initiate a more intensive training period, because the technique is already mastered and will not influence the intensity of training.

Only one study that evaluated deep water training for 12 weeks was found. This study showed a significant improvement in balance in older women[13]. However, this study did not show a period of training at low intensity to familiarize participants with deep water running technique and did not show a progression of training. Thus, arises the question of how is the balance of the improvements along a 16-week linear periodization training in deep water, which is divided into an initial part of a four-week low intensity using exercises that emphasize familiarization with technical and to aquatic environment; and a second part of longer duration (12 weeks) divided into three mesocycles high intensity emphasizing only deep water running execution. Furthermore, another aspect which appears to be important, in contrast to abovementioned study, it is carrying out a study evaluating older men balance. Thus, the aim of the present study was to evaluate the effect of 16 week to deep water running training on the static balance of older men. The hypothesis of the present study is that throughout periodization will occurs an improvement of static balance and that improvements will be observed both after the familiarization period and after aerobic training period of high intensity.

Material and method

Experimental design and approach to the problem

To understand the effects of deep water exercises on static balance in healthy older men, one group performed 16 weeks of deep water training. The first four weeks (weeks 0-4) was performed a low intensity training twice a week, emphasizing familiarization exercises with the aquatic environment and deep water running. In the following weeks (weeks 5-16) was performed a high-intensity training, three times a week, using only deep water running. It was decided to non-inclusion of a control group, since it is already documented in the literature that physical exercise can provide significant improvements in balance[6,11,19,20] and the aging worsens this aspect[4,21]. Thus, does not appear to appropriate, from an ethical point of view, maintaining a group of older people for 16 weeks without the possibility of performing physical exercise. Static balance was evaluated at three time: week 0, 5 and 17; in four out of water position: double- and single-legged stances with eyes open and eyes closed. All assessments were conducted by the same research investigator and were conducted on the same equipment with identical subject/equipment positioning and at the same time of day.

Participants

Participants for this study included 22 healthy older men, aged between 60 and 75 years, who were not engaged in any regular systematic training program in previous three months. Characteristics of the participants are presented in Table 1. Only men were prioritized so that sample was more homogeneous avoiding physiological differences between genders interfering with the results. The participants volunteered for the present investigation following announcements in a widely read local newspaper. Exclusion criteria included any history of neuromuscular, metabolic, hormonal and cardiovascular diseases. Participants were not taking any medication that affected hormonal or neuromuscular metabolism. Medical evaluations were performed using clinical anamnesis and an effort electrocardiograph test. The study was conducted according to the Declaration of Helsinki and was approved by the Ethics Committee of Federal University of Rio Grande do Sul, Brazil. Based on the variances of prior studies performed in our research group, the calculation of the sample "n" was carried out using the G POWER software (version 3.0.1.) with a statistical power of 80%.

Table 1. Participants characteristics.

n= 22	Mean	±SD
Age (years)	65.2	3.8
Body mass (kg)	82.0	22.6
Height (m)	1.78	0.1
Percent fat (%)	16.3	8.1

Assessements

Physical Characteristics

Body mass and height were measured using an Asimed analog scale (resolution of 0.1 kg) and Asimed stadiometer (resolution of 1 mm), respectively. Body composition was assessed using the skinfold technique. A seven-site skinfold equation was used to estimate body density[22] and body fat was subsequently calculated using the Siri equation[23].

Balance evaluation

Performance tests were conducted before training period (week 0), after familiarization period (week 5) and after high intensity training (week 17). Balance was measured using a triaxial accelerometer (MicroStrain, 3DM-GX2 model, Williston, VT, USA) at the hip of participants using a neoprene belt. Care was taken to position the instrument over L5 region.

All participants wore comfortable clothing and shoes of their choice to perform the tests. For assessments were necessary two researchers, one responsible for timing, start and end the test and another to support the participant in the event of imbalance. Static balance was measured for 20 s in four positions on land environment: double-legged stance with eyes open, double-legged stance with eyes closed, single-legged stance with eyes open and single-legged stance with eyes closed. The order of these tests was randomized and there was a 5 min interval between each position change. In the tests with eyes open, the participants stood silently on the meter staring at a point marked on the wall (distance was 3 m forward and height was 1.5 m). In the double-legged stance tests, the participants were instructed to maintain spacing between their feet that did not cross the shoulder lines. For the data analysis, we excluded the first and last 5 s to avoid variations of position changes, resulting in 10 s of data for each task. The accelerometer had six A / D converters to ensure that all sensors presented simultaneously and was calibrated for sensor misalignment. The sampling frequency used was 100 Hz. Following signal acquisition, the data were exported to the Matlab software which calculated acceleration Root Mean Square (RMS) values according to O´Sullivan et al.[24]. For the RMS values, we used the resultant acceleration of the three axes that were evaluated (medio-lateral, anterior-posterior and vertical).

Training program

The training program was divided into four four-week mesocycles, totaling 16 weeks of intervention. The first mesocycle (weeks 0-4) was

Figure 1. Illustration of some of the exercises used during familiarization period.

conducted twice weekly, on nonconsecutive days; thus, totaling 8 sessions of 45 minutes each. The exercises were performed using a flotation device, without feet touching the bottom of the pool. All sessions were conducted as follows: (1) warm-up exercise; (2) fluctuation in the supine position, lateral and ventral; (3) alternating decubitus positions; (4) displacements across the pool using only upper limbs; (5) exercises to perfect the technique of deep water running; and (6) stretching. Some of the exercises used can be observed in Figure 1. The intensity of the exercise was Borg category scale [9] (very light) as measured by the Rating of Perceived Exertion (RPE). The exercise program was conducted at an indoor swimming pool that had a water depth of 1.98 m and a water temperature of 30-32 ºC.

In the following mesocycles, the participants trained on nonconsecutive days, three times per week for 12 weeks (weeks 5 to 16); totaling 36 sessions. The training sessions lasted 45 min; the first part was used to warm up, and the end of the session was used to stretch the main active muscle groups used in the session. The main part of the session had lasted 30 minutes in which there has been aerobic interval training in deep water running. The training intensity was controlled using individual heart rate corresponding to anaerobic threshold (HR_{AT}), determined in a maximal deep water running test and controlled by a HR monitor (Polar, FS1)[25]. During the first 4 weeks, participants performed 6 bouts of 4 min at 85-90% of HR_{AT} (weeks 5-8), with 1 min of active recovery between bouts at below 85% of HR_{AT}; in the weeks 9-12, participants performed 6 bouts of 4 min at 90-95% of HR_{AT}, with 1 min of active recovery between bouts at below 85% of HR_{AT}; and in the last 4 weeks (weeks 13-16), the participants performed 6 bouts of 4 min at 95-100% of HR_{AT}, also with 1 min of active recovery between bouts at below 85% of HR_{AT}.

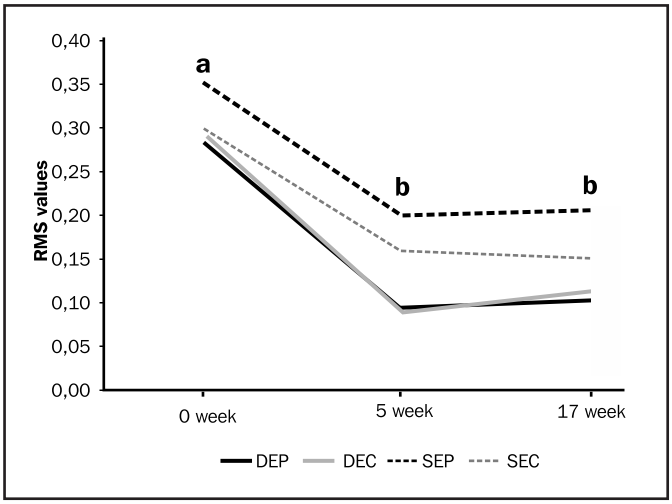
Statistical analysis

Results are reported as mean and standard deviation. Normal distribution and homogeneity parameters were checked with Shapiro-Wilk and Levene test's respectively. ANOVA and Bonferroni were used to comparisons over time. Retrospective statistical power provided by SPSS after analysis was equal or greater than 0.873 in all variables. Significance was defined as α=0.05. The SPSS statistical software package (version 20.0) was used to analyze all data.

Results

Static balance evaluated in different stances showed significant differences over time (p<0.05). From the post-hoc test was observed that week 1 to week 4 there was a decrease in the RMS value in all positions, which represents an improvement in static balance. The percentage of improved in double-legged stance eyes open was 34% and in eyes closed was 32%, furthermore, in single-legged stance eyes open was 56% and in eyes closed was 53%. Moreover, week 5 to week 16 (corresponding to high intensity training) there was a maintenance of these values, in all stances evaluated (Figure 2).

Figure 2. Static balance response over time in the double-legged stance, eyes open (DEP) and eyes closed (DEC), and in the single-legged stance, eyes open (SEP) and eyes closed (SEC) positions. Different letters represent significant differences on balance over time in all cases evaluated (p<0.05).



Discussion

The results confirm in part the hypothesis of this study, since it was observed an improvement in the balance of participants in the intervention. However, this improvement was only observed after the first four weeks for familiarization with the aquatic environment and technique of deep water running. The following period, corresponding to aerobic training of high intensity only with deep water running, was effective for the maintenance of improvements.

The decrease in RMS values in all evaluated positions after the first period of the training, corresponding to low intensity training, showing a significant improvement in balance for all participants. The pattern of oscillation of the body is still not clearly understood, but it is believed that most proprioceptors adapt to variations and reduce their responses[26]. This behavior can also affect sensorimotor mechanisms involved in balance control during unstable positions. Thus, low frequency oscillations during static postural positions can allow the system to receive updated information on movements and positions at an appropriate pace[27]. Furthermore, RMS values in all stances evaluated remained similar after the high intensity training.

In the literature, there are no studies evaluating balance throughout an aquatic periodization and few studies have evaluated balance after an intervention in an aquatic environment and findings have been widely varied[11,13,19,28-31]. In a study of older people by Simmons & Hansen[28], the authors found that two sessions per week in an aquatic environment, for a five week intervention period, may be sufficient to improve parameters related to balance that were evaluated by functional tests. Training was performed in shallow water and used different exercises that aimed to cause instability. Thus, results of the present study and the above study show that the balance can be improved after a short period of intervention in water. Furthermore, in each session of the present study, the emphasis was on exercises that familiarized the subject with the aquatic environment, the use of the float vest and the technique of deep water running. To this end, exercises were performed in different decubitus positions, with changing positions and with displacements without the use of the lower limbs. Moreover, execution of these exercises in deep water further optimized instability because of the open kinetic chain nature of the exercises, as previously described. In a similar context, a recent systematic review indicated that exercises that include progressively difficult postures, with a reduced support base, and dynamic movements that perturb the center of gravity and provide a stress to postural muscle groups are the most likely to provide improvements in the balance of older adults[32]. Therefore, the exercise characteristics may have been fundamental in explaining the significant improvements in balance.

Longer studies evaluating balance in older adults were also found in the literature. However, only one of them involved exercise training in deep water. In a 12 week intervention period, with twice weekly frequency, Kaneda *et al.*[13] compared the effects on balance in older adults of two aquatic exercise programs, deep water running and water aerobics. The training sessions consisted of 10 minutes of warm-up on land and 20 minutes of walking exercises (walking forward, backward, sideways, with kicking, torso twisting and knee-ups, etc.) in shallow water for both groups. Following this, one group moved to deep water to perform basic movements of walking and running and the other group remained in the shallow water to perform basic movements of walking, plus some resistance exercises. Lastly, both groups had a 10 minute rest, followed by 10 minutes of recreation and relaxation in the water. Both groups showed an improvement in balance in a double-legged stance with eyes open and eyes closed, as assessed by a posturographic meter from the decreased range of postural sway (cm) and area of postural sway (cm^2). Furthermore, the group that had trained in deep water showed a decrease in time for performing the Tandem-walking test. Thus, based on these results, the authors concluded that both training approaches seemed to be effective in improving static balance. However, it is difficult to know whether the improved balance resulted from the main part of the training session, performed by one group in shallow water and the other group in deep water, or from the exercise portions that were the same for both groups (for example, walking at different offsets, which produces greater instability) because the static balance responses were similar for both training groups.

Also using a longer intervention period and older adults participants, Lee et al.[31] compared 12 weeks of balance training in an aquatic and a land environment. Evaluation was performed using the *Good Balance System* (Finland), which is similar to that of a force platform system. The results showed a decrease in mean velocities (mm/s) in both groups, both in a medio-lateral and an antero-posterior direction, in a double-legged stance with eyes open and closed. Regarding dynamic balance, both groups showed improvement, however, the group that conducted the training in water showed more significant improvements compared to the group that trained on land. Therefore, the authors believe that water stimulates proprioceptors that help in the development of balance. According to the authors, the interaction of gravity and buoyancy during movements in water, especially in situations of postural sway, actively stimulates proprioceptive mechanoreceptors to decrease this postural sway.

In the present study, the high intensity training in deep water did not improve the balance diverging results found in studies previously cited. However, were efficient to keep what had been improved in the first period. Moreover, the different methods employed, both in relation to the duration of training and with regard to the different assessment techniques to measure balance, hinder the comparison between studies. However, the results found in the literature and in this study demonstrate that exercises that involve greater instability and challenges to posture maintenance seem to be the most useful for improving balance, with an aquatic environment being an interesting tool to optimize these responses in dynamic and static balance. Furthermore, the different assessment instruments also make comparisons difficult. In the present study, balance was assessed using an accelerometer, which is a relatively new tool for such evaluations. According to the literature review by Groot *et al*.[33], up until their publication date, no studies assessing balance with an accelerometer had been found. However, this same study recommended the use of an accelerometer because of its easy application and lightweight and compact design that allows it to be used in static and dynamic situations. Complementing this information, Moe-Nilssen&Helbostad[26] claim that the high sampling frequencies of accelerometers help distinguish differences in postural control during static positions, for example, between the double-legged position with eyes open and eyes closed.

One of potential limitations of this study was not using a control group that could give greater methodological quality at the same. Moreover, it could have been inserted an assessment of dynamic balance that possibly could also respond significantly the second part of the training and could even increase the practical applicability of the study. For future studies it is suggested to compare different training strategies in deep water in balance responses, such as using different intensities and different exercises.

Despite the above limitations, the study showed significant results to support the prescription of training in deep water that aims at improving balance in older men. To the present date this seems to be the first study to assess the balance over a periodization in the aquatic environment, demonstrating the effectiveness of the realization of the familiarization period in improving balance. We also highlight that according to our results and the literature, exercises with greater instability that generate a greater postural control are more efficient in the improvement of this variable. In this context, the aquatic environment is a safe environment for their realization, as it allows the execution of postures that on land become more susceptible to falls. Finally, the period of high intensity aerobic training, showed a maintenance effect is also an important result since aging is accompanied by a significant loss of balance[4,21].

In conclusion, the results of the present study demonstrate that a short-term, four week of familiarization exercises to both the aquatic environment and deep water running technique were able to induce significant improvements in the static balance of older men. In addition, aerobic deep water running training was sufficient to maintain these gains. This result is important because it demonstrates that the practice of exercises in deep water helps not only to familiarize individuals with the modality but also to provide improvement in balance, which may reflect an improvement in postural control, thus preventing possible falls and functional dependence.

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