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Original Research

Acute Effects of Velocity-Based Resistance Training on the Physical Functional Performance of Older Adults

SUZY S. PINTO†[1], EWERTTON DE S. BEZERRA‡[2], KEULY G. SILVA*[2], RODRIGO RAMIREZ-CAMPILLO‡[3,4], and ABDERRAOUF BEN ABDERRAHMAN‡[1]

[1]Higher Institute of Spot and Physical Education of Ksar Saïd, University of Manouba, Manouba, TUNISIA; [2]Human Performance Laboratory, Federal University of Amazonas, Manaus, BRAZIL; [3]Human Performance Laboratory, Department of Physical Activity Sciences, University of Los Lagos, Osorno, CHILE; [4]Exercise and Rehabilitation Sciences Laboratory, School of Physical Therapy, Faculty of Rehabilitation Sciences, Universidad Andres Bello, Santiago, CHILE.

*Denotes undergraduate student author, †Denotes graduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 15(3): 399-413, 2022. The aim of this study was to analyse the acute effects of velocity-based resistance training on the physical and functional performance of older adults. Twenty participants (70.4 ± 7.4 years) performed the deadlift exercise, in two different resistance training protocols. The moderate-velocity protocol (MV) predicted maximum loads so that the movement velocity during the concentric phase remained in the range of 0.5 to 0.7 m/s and the high-velocity protocol (HV) predicted maximum loads so that the movement velocity remained between 0.8 and 1.0 m/s. The jump height (cm), handgrip strength (kg), and time (s) to complete the functional tests were assessed before (baseline), and immediately (post), 24-h, and 48-h after the MV and HV protocols. Compared to baseline, both training protocols acutely led to a gradual reduction in walking velocity, with significant values 24 hours after training ($p = 0.044$), on the other hand, both protocols improved performance in the timed up and go test at post ($p < 0.001$) and in the sit-to-stand test at 48-h ($p = 0.024$), although there were no significant differences between them for any times analysed ($p > 0.05$). No other outcomes exhibited significant changes. Results indicate that neither of the protocols (MV and HV) led to significant impairments in physical function of the older adults, and can be recommended with the safety criterion of at least 48-h of rest between sessions.

KEY WORDS: Human physical conditioning, physical education and training, fast-twitch muscle fibres, physical functional performance, aging

INTRODUCTION

Aging is a natural and inevitable phenomenon, characterized by a decrease in physical and functional capacities (7). This deterioration occurs at different levels and progressions and affects many body systems, including the neuromuscular system (28), with reduction such as loss of motor units, neuronal atrophy, reduction in conduction velocity of action potential, deceleration of the transmission of the neuromuscular response, and loss of muscle mass (sarcopenia). These alterations are related to a reduction in strength and muscle power and can significantly impact the metabolic health, mobility, and independence of older adults (24, 27, 35). One of the strategies used to minimize the harmful effects of aging is the regular practice of physical activity (7, 12, 44), with resistance training programs being the most effective when it comes to the prevention and delay in the process of sarcopenia due to aging (31). This type of training leads to an increase in the cross-sectional area of muscle fibres (hypertrophy) (38), accelerates the rate of muscle protein synthesis (1), and favours the increase in muscle strength and power (24), which provides improvements in the ability to perform activities of daily living (8).

Although several long-term benefits can be derived from a resistance training program, some acute effects can include muscle damage such as delayed onset muscle soreness, swelling, (13), and a temporary reduction in maximum strength, range of motion (5, 17), and muscle power (9). This damage, when excessive, can cause a risk of injury and even greater loss of cognitive and functional skills in older people.

The acute muscle fatigue generated by resistance training can last for several hours or even days and the recovery time, which is generally slower in older people (5), varies according to the type of physical function and the intensity of the training (33). Different investigations that study the acute effects of resistance training in older adults highlight the intensity of the training. In the study by Orssatto *et al.* (33), the authors compared the effects of moderate and high intensity strength training (60 vs 80% of a maximum repetition or 1-RM) on the recovery of the oldest old. The authors observed an acute reduction in explosive strength, with faster recovery after moderate intensity training compared to high intensity training. Ferri *et al.* (18) investigated the recovery of strength after a heavy-resistance training session on the calf muscles of older adults. The results showed a reduction in peak torque 5 minutes after training and full recovery after 24 hours of rest. Häkkinen (23) examined neuromuscular fatigue and the recovery of women in three different age groups, after performing a protocol of strenuous heavy resistance exercises and found a gradual decrease in muscle strength and a 95% recovery of initial strength values after two days of rest for the group of older women.

It is important to note that the intensity of the training is commonly determined by percentage of 1-RM, number of maximum repetitions (X-RM), or rating of perceived exertion (RPE). Although these methods are valid, reliable, and do not require monitoring equipment, they are time-consuming procedures, require periodic reassessments, and, in the case of RPE, it is a subjective measure (2). Therefore, different researchers have started to apply, as an alternative method, velocity-based training (2, 37, 39). This method allows the prescription and monitoring of training load, provides real-time responses, and allows adjustments with more objectivity and without the need for maximum load tests. Velocity-based resistance training is based on the inverse relationship between load and velocity, allowing the training load to be adjusted as the participant is no longer able to produce the necessary velocity during the training session. That is, if muscle contraction velocity is less than the velocity idealized for the training session, the load must be reduced, while, on the contrary, if muscle contraction velocity is faster, more load should be added (2). The great advantage of velocity-based resistance training is the ability to work with optimal loads and avoid unnecessary fatigue and training to failure (2, 37, 39), points of great importance when the training audience is older people. The close relationship between load intensity percentages and muscle contraction velocity ranges was presented in the study by González-Badilo & Sánchez-Medina (22). According to the authors, for muscle work performed at the intensity of 80 to 100% of 1-RM, the equivalent velocity would be 0.19 to 0.48 m/s, while for the intensity of 30 to 60% of 1-RM, the equivalent velocity would be from 0.80 to 1.33 m/s.

Although researchers generally agree with the potential benefits derived from velocity-based resistance training, most studies have been conducted with young athletes and / or investigated long-term effects. Therefore, understanding the dynamics of recovery of older people in the hours following training sessions based on moderate and high velocity is of great value and will allow us to provide ideal recommendations for muscle training for this population. Thus, the aim of this research was to analyse the acute effects of velocity-based training on physical and functional performance of older people. We expected that the proposed training protocols (high-velocity [HV] and moderate-velocity [MV]) would induce some degree of muscle damage and that functional performance would be reduced when measured hours after the training session. We hypothesized that the MV protocol would cause greater muscle damage than the HV protocol, requiring more time for muscle power and functional performance recovery in older adults.

METHODS

Participants

The subjects were recruited by oral invitation or posters and pamphlets in centres for older adults and social clubs. To be included, volunteers were required to be 60 years of age or older and able to complete the training sessions and physical fitness tests. The exclusion criteria were having practiced RT in the three months before the study, an unstable cardiovascular disease, dysfunction of the endocrine system, diabetes, sensorial problems, musculoskeletal and/or neuromuscular disease of the lower limbs or chronic pain, or musculoskeletal discomfort that precluded exercise.

Thirty subjects expressed an interest in the study, however only 8 men and 12 women were eligible and completed baseline tests. The volunteers were randomly allocated to two velocity-based resistance training protocol groups: high-velocity (HV) and moderate-velocity (MV). After two-weeks of rest, a cross-over procedure was applied for inversion of the protocols. During the experiments 9 participants did not complete one of the training protocols and / or did not complete the evaluations after the training protocols. Therefore, from the 20 older adults who were eligible to participate in the study, 16 completed the MV protocol and 15 the HV protocol. The final sample size is considered satisfactory ($n > 10$), calculated using the GPOWER program (G*Power; University of Düsseldorf, Dusseldorf, Germany) with a target effect size = 0.86 (based on a previous research investigating the effects of velocity-based strength training on functional performance of lower limb strength in older females (6)); alpha = 0.05; non-sphericity correction € = 1; correlation between measures repeated = 0.5 and power = 0.80, given the study design (2 groups, 4 repeated measures).

Subjects were asked not to change their lifestyle during the trial period and not to take anti-inflammatory drugs or food supplements. All volunteers signed the consent form, and the study was approved by the Ethics and Research Committee of the Federal University of Amazonas (CAAE: 18425619.0.0000.5020) and performed in accordance with the Helsinki declaration. This research was carried out in full agreement with the ethical standards of the International Journal of Exercise Science (32).

Protocol

A crossover randomized blind design was used to compare the acute effects of two different protocols of velocity-based resistance training on muscle power and functional performance in older adults. The study had a total of 15 visits (i.e., 6 weeks). On the first visit, the subjects were informed about the study design and procedures and anthropometric measurements were collected. During the second, third, and fourth visits, each separated by 48 hours, subjects were familiarized with the tests and exercises. In the following week, three more visits were carried out to apply the baseline assessments, in which subjects were tested and retested in: 1) deadlift velocity-based submaximal load test; 2) vertical jump test; 3) maximum handgrip strength; and 4) functional performance (without and with motor dual-task). Subsequently, subjects were randomized into two groups. Each group performed two resistance training sessions of MV or HV protocols. Immediately after the second training session (post), the subjects performed vertical jump, maximum handgrip strength, and functional tests. These same tests were repeated on subsequent days (i.e., 24 and 48 hours later). After two weeks of washout, a crossover design was applied. The subjects performed two more training sessions with different protocols of velocity-based resistance training, and after each training session, tests followed the same format (post, 24-h and 48-h) (Figure 1). The same evaluator analysed all tests at all times, and he/she did not know about the randomized group distribution.

Body mass (kg) was measured with an electronic scale (Balance NRBF701-17; accuracy: 0.1 kg) and standing height (m) with a tape measure attached to a wall. The body mass index was calculated using the formula kg/m^2, where kg is the body mass value in kilograms and m^2 is the height value in metres squared. The waist and hip circumferences (cm) were measured using a tape measure. For the waist circumference, the measurement was taken in a horizontal plane on the narrowest region of the waist, equidistant from the bottom of the ribs and the pelvic bone (iliac crest). For the hip circumference, the measuring tape was placed around the hips, in a horizontal plane. The waist-to-height ratio was calculated by waist circumference divided by hip circumference.

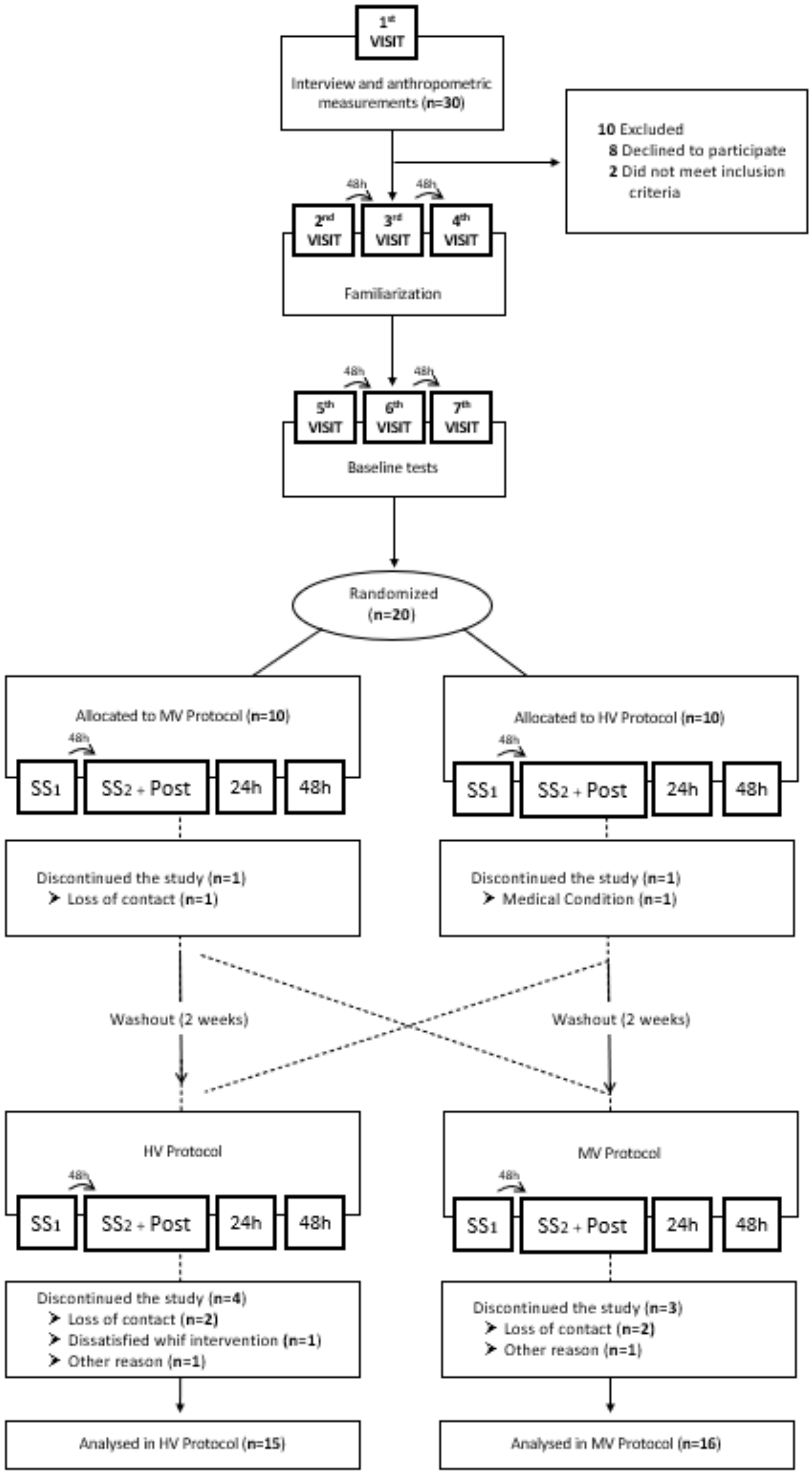

Figure 1. Study design. Total of 15 visits (i.e., 6 weeks). SS1 = first resistance training sessions. SS2 = second resistance training sessions. HV: high velocity protocol. MV: moderate velocity protocol.

The velocity-based submaximal load test was performed on 2 days: on the first day, after a dynamic warm-up with mobilization of the lower and upper limbs using a free barbell and a pre-conditioning deadlift exercise with one set of 10 repetitions at a load of 10% of body weight, each subject performed five trials (separated by a 2-minute interval) of 6 repetitions of the deadlift exercise. Participants were instructed to produce force "as fast as possible". The initial load in the test was 15% of body weight, which increased or decreased by 5% according to the monitored execution velocity (target velocity range = 0.75 to 1 m/s). After a 15-minute recovery, subjects performed another test to achieve the execution velocity of 0.50 to 0.74 m/s, following the same load adjustment and the same number of trials and repetitions. On the second day, 48 hours later, the test followed the same settings as the first day (dynamic warm-up, pre-conditioning and five trials of 6 repetitions of the deadlift exercise), however initial load was defined as the highest load obtained on the first day and the order of the velocity was inverted to avoid possible influences of the order of application. In addition, the initial order of tests was randomized. Velocity control during the exercise was performed using an accelerometer (Push training 2.0; Toronto, Canada) connected to the barbell. The average velocity of each repetition was recorded, and the maximum load obtained during the two days was defined as the training load. The subjects were instructed not to exercise between the two test days.

The height of the jumps (cm) was evaluated by the mobile application *My Jump*, recorded by a mobile phone (iPhone 7; Apple, Cupertino, California, United States) at a sampling frequency of 240 Hz (16). For the countermovement jump (CMJ), the subjects started from the standing position, followed by a downward countermovement (i.e., bending of the lower limbs) and then, immediately, by complete extension of the lower limbs. For the squat jump (SJ), the subjects started with their knees bent, then jumped without performing a countermovement before the jump. During the execution of the tests, the subject was asked to jump as high as possible, keeping their hands on their hips to avoid any pendulum movement with the arms (21). The maximum knee flexion (during the CMJ pushing phase and at the start of the SJ) was predetermined at 70º (19). This measurement was carried out during the familiarization period, using a goniometer (Baseline®, Aurora, IL, USA).

The maximum isometric strength of the forearm muscles (handgrip strength test) (kg) was measured in both dominant and non-dominant hands, using an adjustable digital hand dynamometer (Electronic Hand Dynamometer, EH101, Italy), certified by the European Community (EC). The subjects were instructed to exert a maximal grip for 5 seconds. The volunteers were placed seated on a chair in an erect position, with a 90° hip, knee, and elbow flexion position, with the shoulder adducted and neutrally rotated, the forearm in a neutral position and the wrist in slight extension (0° to 30°). Three grip-strength measures of each hand were taken, with the best result chosen for analysis. To obtain the relative muscular strength of the upper limbs, the grip strength was normalized by body weight (36).

Functional performance (s) was evaluated by three tests in the following order: sit-to-stand, timed up and go, and walking test. Muscle strength and power capacity of the lower limbs was measured by the five times sit-to-stand test. This test consisted of standing up from a chair and returning to the initial seated position, completing five repetitions as quickly as possible (43).

Agility and balance were assessed using the timed up and go test (TUG), which consists of measuring the time to perform the task of standing from a chair, walking 3 m, turning, going back, and sitting down on the same chair (10). To measure gait velocity, the 6m-walking test was used. In this test the participants were instructed to walk quickly and safely for 8 m, striving without overdoing it. Although participants walked 8 m, only the travel time of the first 6 m was recorded. This strategy is used to prevent the individual from slowing down at the end of the course (43). To assess the interaction between the two motor tasks, participants were invited to perform the walking test and TUG holding a cup with 200 mL of water in the dominant hand (11). Each subject performed two attempts of each test and the fastest time was used for further analyses. All the tests were filmed using a mobile phone (iPhone 7; Apple, Cupertino, California, USA) with a sample rate of 240 Hz and analysis was performed with the help of specialized software (Kinovea®, France).

The RPE was measured just after the end of each training session, using the Omni-Res perceived exertion scale (26). This scale is made up of intensity levels varying from 0 (extremely easy) to 10 (extremely hard). Participants were familiarized with the scale before the training session.

Resistance training sessions were organized as follows: before the training session, the participants performed a dynamic warm-up. After 2 minutes of rest, the training session began with the deadlift exercise. Volunteers randomized into the MV protocol, performed 3 sets of 10 repetitions, with a maximum load so that the movement velocity during the concentric phase of each repetition remained within the velocity range of 0.5 to 0.7 m/s. For the HV protocol, the participants performed 5 sets of 6 repetitions, with a maximum load within the velocity range of 0.8 to 1.0 m/s. The eccentric movement phase of the repetitions was performed in 2 to 3 seconds, and the rest interval between sets and exercises was 120 seconds.

Statistical Analysis

The SPSS Statistical Software package (version 18.0) and Graph Pad Prism (version 6.0) were used to analyse all data. The data were first analysed using descriptive statistics. Normal distribution parameters were evaluated with the Shapiro–Wilk test. The intra-rater reliability intra-class correlation was used to reflect the variation of data measured by one rater across two or more trials, and was classified according to Koo (25). Values < 0.5 are indicative of poor reliability, 0.5-0.75 indicates moderate reliability, > 0.75-0.9 indicates good reliability, and > 0.90 indicates excellent reliability. Countermovement jump, squat jump, maximum handgrip strength, five time sit-to-stand, timed up and go, 6-m walking, and motor dual-task baseline results were set as 100%. The percentage of the subsequent test results (post, 24-h and 48-h) were calculated relative to baseline. To compare differences between groups in baseline training velocity and absolute training load, a Student *t*-test for independent samples was used, while for relative training load and the perceived exertion scale a Wilcoxon test was applied. An analysis of variance (ANOVA) with repeated measures was used to analyse main effects as well as the interaction between treatments (MV, HV), and also, the interaction time vs treatment [(MV, HV) × time (baseline, post, 24-h and 48-h)] for the percentage values of each of the tests performed. When significant *F*-values were identified, the Bonferroni post-hoc test was performed to identify pairwise differences. Effect sizes were calculated based on partial eta-squared (η_p^2), and classified according to Cohen (15), with 0.20, 0.50, and 0.80 considered small, moderate, and large, respectively. An alpha level of 5% was used in all statistical analyses.

RESULTS

Comparisons of absolute and relative load values, movement velocities, and rate of perceived effort during MV and HV sessions are presented in table 1. Resistance training parameters (load in kg and velocity in m/s) were significantly different between treatments ($p \leq 0.01$). Participants in the HV protocol trained with a smaller load (absolute and relative) than in the MV, and for this reason they reported a lower rate of perceived effort.

Table 1. Comparison between moderate velocity (MV) and high velocity (HV) resistance training sessions.

	MV protocol	HV protocol
Training load (kg)	33.28 ± 17.01	11.03 ± 5.66#
Training load relative to body mass (kg/kg)	0.50 ± 0.22	0.16 ± 0.06*
Velocity (m/s)	0.56 ± 0.06	0.89 ± 0.06#
RPE	4.53 ± 1.27	2.03 ± 1.06*

Values are mean ± SD. * = significant difference between treatment groups with Wilcoxon test ($P \leq 0.01$). # = significant difference between treatment groups with Student-*t* for dependent variables ($P \leq 0.01$). RPE: Rate of perceived exertion (0–10 Omni-Res).

A time effect was observed for squat jump height ($F_{(3,87)} = 4.31$; $p = 0.007$, $\eta p^2 = 0.129$), without differences between treatments. Squat jump height at 48 hours was greater compared to 24 hours ($p = 0.003$) (Figure 2A), whereas no significant changes were observed for countermovement jump height (Figure. 2B).

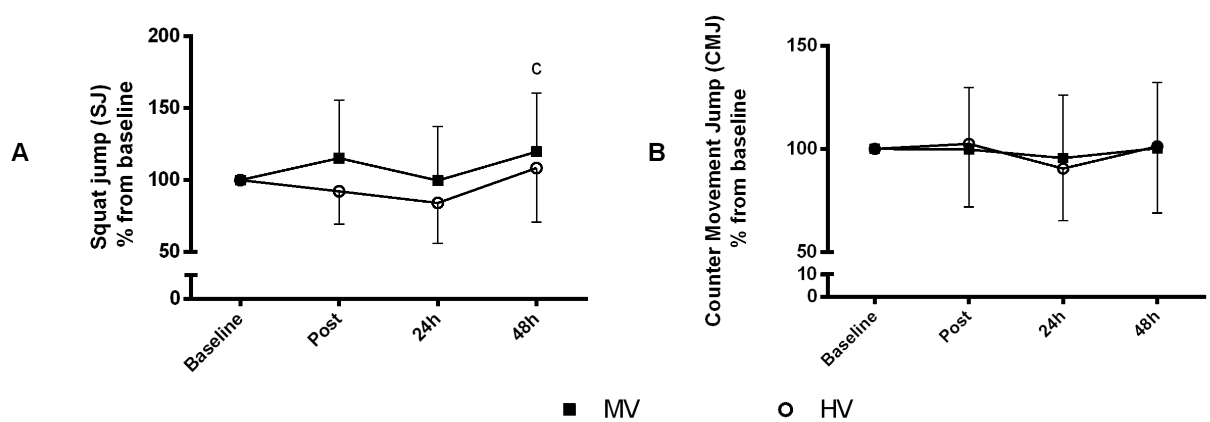

Figure 2. Changes in vertical jump height among older adults after moderate velocity (MV) and high velocity (HV) resistance training sessions. A) Squat jump and B) Countermovement Jump. Values expressed as relative (%; means ± standard deviation) changes compared to before (baseline), right after (post), and 24-h and 48-h after the training sessions. c: $p < 0.05$ compared to 24-h.

For functional capacity tests, significant main effects for time were observed in the five times sit-to-stand ($F_{(3,87)} = 4.22$; $p = 0.008$, $\eta p^2 = 0.127$), timed up and go ($F_{(3,87)} = 4.56$; $p = 0.019$, $\eta p^2 = 0.136$), and 6-m walking ($F_{(3,87)} = 3.81$; $p = 0.013$, $\eta p^2 = 0.116$) without differences between treatments.

The time in the five times sit-to-stand at 48-h was lower than baseline ($p = 0.024$) (Figure 3A). The timed up and go at post was lower than baseline ($p < 0.001$) (Figure 3B). However, 6-m walking time at 24-h was higher than baseline ($p = 0.044$) (Figure 3D). No significant changes were observed for dual-task activities ($p > 0.005$) (Figures 3C and 3E).

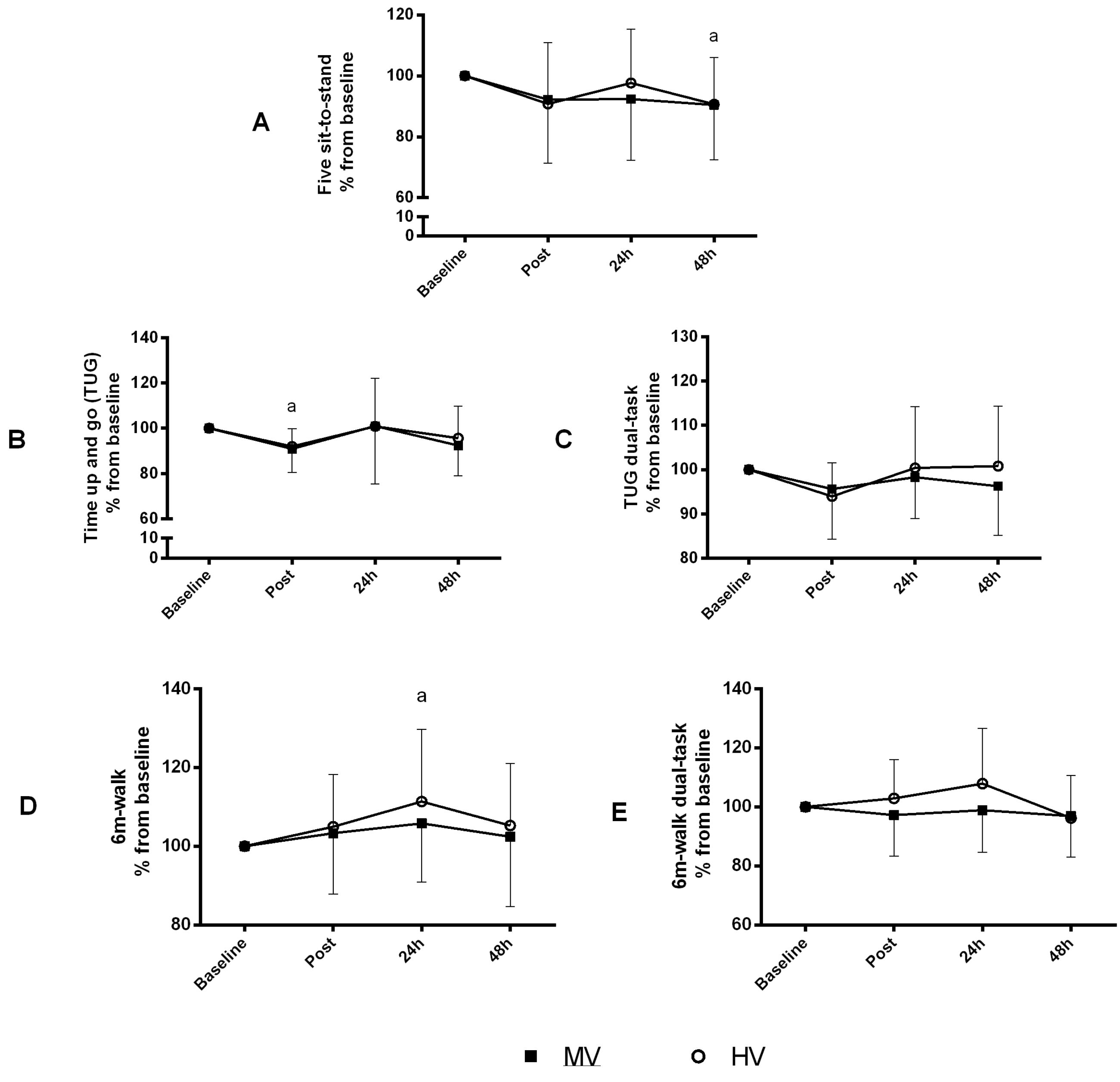

Figure 3. Changes in physical functional performance among older adults after moderate velocity (MV) and high velocity (HV) resistance training sessions. A) five times sit-to-stand test; B) timed up and go test (TUG); C) TUG dual-task; D) 6m-walking test; and E) 6m-walking dual-task test. Values expressed as relative (%; means ± standard deviation) changes compared to before (baseline), right after (post), and 24-h and 48-h after the training sessions. a: $p < 0.05$ compared to baseline.

For dominant and non-dominant handgrip, the absolute and relative values of strength did not significantly change in the time following MV and HV resistance training sessions ($p > 0.05$). Compared to baseline (100%), absolute and relative strength values of the right hand immediately after MV resistance training sessions decreased 0.2%, and increased immediately after HV by 3.5%. At 24-h after, decreases of 4% and 3.5% were observed for MV and HV respectively and at 48-h after, increases of 0.8% and 0.9% were observed for MV and HV respectively. Regarding absolute and relative strength values of the left hand, immediately after MV and HV resistance training sessions decreases of 2.7% and 1.0% were observed, respectively. At 24-h an increase of 1.9% and a decrease of 2.1%, respectively, and at 48-h, an increase of 2.7% and a decrease of 0.2%, respectively. The variation in individual responsiveness between participants of MV and HV for vertical jump, maximum handgrip strength, and functional capacity tests are presented in Figure 4.

The test-retest reliability of SJ and CMJ (0.984 and 0.972, respectively), maximum handgrip strength left and right (0.952 and 0.950, respectively), 6-m walking and 6-m walking with dual-task (0.956 and 0.939 respectively) demonstrated excellent reliability, while five times sit-to-stand, timed up and go, and timed up and go with dual-task tests (0.74, 0.520, and 0.663 respectively) demonstrated good reliability.

DISCUSSION

The objective of this study was to analyse the acute effects of velocity-based training on the physical and functional performance of older adults. The main results showed positive recovery in muscle power and functional performance, except in the 6m walking test, after two training sessions for both velocity-based training protocols (MV and HV), rejecting our first hypothesis that high-velocity resistance training would be more efficient than moderate-velocity resistance training. Therefore, our results confirm the benefits of using velocity-based training (independent of velocity) for older adults, reinforcing the concept that it is possible, with load optimization, to minimize mechanical stress and neuromuscular fatigue after training.

Previous studies indicate that performance of a maximum vertical jump can be considered an indirect indicator of the explosive capacities of the lower limbs (16, 30, 34, 41). In addition, this variable proved to be a good predictor of the functional capacity to perform daily life activities in older adults (8). Orssatto *et al.* (33) observed an immediate reduction in CMJ performance followed by a fast recovery 24-h after a training session with moderate and high intensity (70% and 95% of 5-RM). A significant reduction in CMJ height immediately after high volume resistance training was also observed by Marques *et al.* (29). However, in the present study no significant changes in vertical jump height were observed when compared to baseline value. Significant changes were observed only for SJ height, comparing heights obtained at 48-h, which were greater than those obtained at 24h. Observing the curve in figure 2, the results indicate progressive, but not significant fatigue of lower limb power 24-h after the training sessions followed by positive recovery 48 hours after.

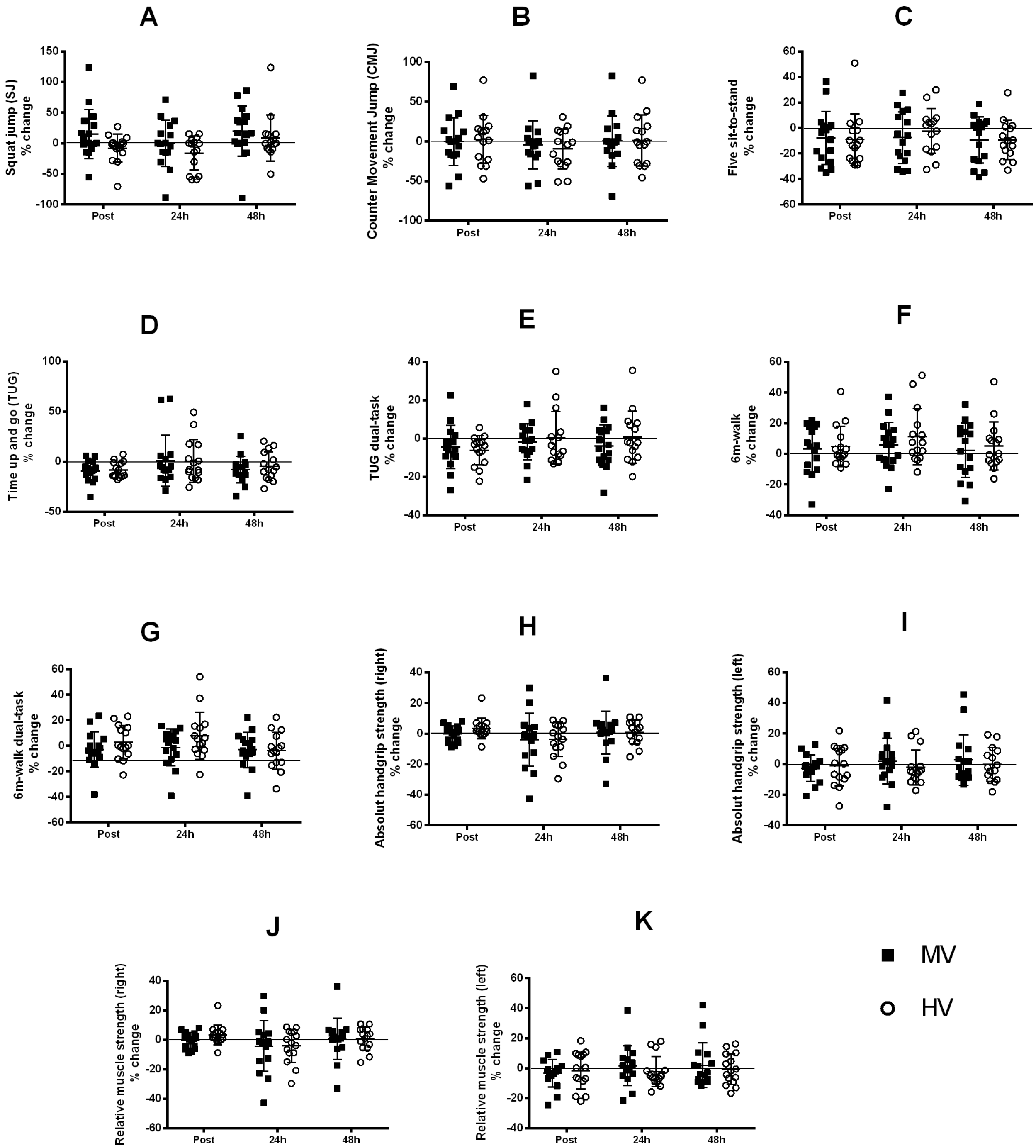

Figure 4. Inter-individual responsiveness, as percentage changes compared to baseline, for squat jump (A), counter movement jump (B), five times sit-to-stand test (C), TUG (D), TUG dual-task (E), 6m-walking (F), 6m-walking dual-task (G), absolute handgrip strength (right hand – H, left hand - I) and relative muscle strength (right hand – J, left hand - K) tests, for both moderate-velocity (MV) and high-velocity (HV) resistance training sessions. Continuous line: MV mean; and dashed line: HV mean.

Regarding functional capacities, significant reductions were observed in the sit-to-stand test time 48 hours after the training sessions; and TUG, immediately after. Similar results were presented by Orssatto *et al*. (33). In their study, the performance of TUG also improved immediately after training, regardless of intensity of training. According to Bassey *et al.* (3), the TUG test, combining walking and getting up from the chair, was significantly correlated with muscle power measured during CMJ relativized by body weight. However, this relationship was not perceived in the current study. Similarity was observed in the responses in the performance of the sit-to-stand test and SJ, as both improved 48h after the training sessions. This similarity is justified, since the ability to sit and stand from a chair is significantly related to power of the knee extensors, in addition to the hamstrings and lumbar muscles that are also among the most active during this test (40). In general, the results of both tests (TUG and sit-to-stand) reinforce the claim that muscle power plays a role in muscle responses to functional capacity tests (33). However, the reduction, although non-significant, in muscle power does not seem to have interfered in the performance of the functional tests in this research, except for the walking test.

According to Vasconcelos (45), gait velocity is a clinical marker of functional capacity in older people, strongly correlated with the ability to generate force of knee extensors, hip muscles, and ankle plantar flexors (4, 8, 14). Impairments in this outcome are associated with disability, falls, and mortality. In the current study, a gradual reduction in walking velocity was observed, with significant values 24 hours after low and high velocity training. The responses of this test seem to be more sensitive to the gradual reduction in muscle power and may be associated with muscle fatigue and the loss of strength of the muscle groups involved in the task (42), requiring 48 hours to recover the initial values.

Although local fatigue was observed for the walking test, the non-significant changes in maximum handgrip strength 48-h after training sessions, indicates that the training protocols used in this study did not induce central fatigue. Furthermore, results of dual-task activities also did not show any significant changes during the 48-h recovery period. According to Gillain (20), in a dual-task test, the additional cortical activity competes with the cortex component. Consequently, the execution of two actions simultaneously disturbs not only postural balance but also the parameters of walking linked to the risk of falling. Thus, these results indicate that the fatigue caused by the training protocols of this research presented no risk of falling for the participants.

Statistical differences observed between the external loads (displacement velocity and absolute and relative loads), confirm the differences between both velocity-based training protocols. This confirmation is also reinforced when the internal load (RPE) of both protocols also presents statistically significant differences. In addition, the present study had some strengths, such as a high internal validity due to the high intra-class correlation coefficient and the use of a randomized design. Another strength of the study was the participation of a homogeneous population of older adults, who were unaccustomed to resistance training. However, the reduced number of participants may have been one of the methodological limitations. We recommend the development of new studies about the acute effects of velocity-based resistance training on the physical functional performance of a larger number of participants, who can be classified according to age, such as older adults (60 and 70 years old) or the oldest old (over 80 years old), or according to their fragility level.

In summary, both velocity-based training protocols showed positive recovery effects in the days after the session. This means that velocity-based training seems to be an efficient and safe method to apply for older people, as it leads to a quick recovery, allowing for more than two sessions per week.

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