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Original Research

# Effectiveness of a Fast- vs. Slow-Velocity Training on Load-Velocity Characteristics in Older Adults: A Pilot Study

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ABSTRACT

***International Journal of Exercise Science 17(7): 1416-1428, 2024.*** Resistance training at fast velocities is suggested to be more effective for improving muscular strength and movement speed compared to slow, heavy training. This study aimed to examine the effects of a fast-velocity (FVRT) compared to a slow-velocity (SVRT) resistance training program on maximal strength, maximal movement speed, and load-velocity characteristics in older adults. Nineteen community-dwelling older adults were randomly assigned to either the FVRT or SVRT group and completed a twice weekly, progressive resistance training protocol for 8-weeks. Both groups were instructed to move the weight "as fast as possible" during the concentric phase of the movement and received movement velocity biofeedback. Absolute ($1RM_{ABS}$) and relative ($1RM_{REL}$) strength, maximal movement speed (MMS), load velocity slope ($LV_{SLOPE}$) and the area under the $LV_{SLOPE}$ ($LV_{AREA}$) were measured during a 1RM assessment at baseline (PRE), after 4-weeks (MID), and after 8-weeks (POST) of training. No differences were observed in average total volume between groups (FVRT: 47490.3±10888.3 kg/session; SVRT: 44679.3±15250.9 kg/session, $p = 0.26$, $g = 0.60$). Both groups improved absolute and relative strength and maximal movement speed. There were no interaction or main effects of $LV_{SLOPE}$ for time. However, there was a main effect of $LV_{AREA}$ for time. Both MID and POST $LV_{AREA}$ were larger than PRE (MID posterior $mean_{diff}$: 0.24, 95% CI: 0.13–0.35; POST posterior $mean_{diff}$: 0.39, 95% CI: 0.27–0.49). These findings suggest both FVRT and SVRT can lead to improvements in strength and movement speed in older adults. The lack of significant changes in $LV_{SLOPE}$ indicates that maximal strength and movement speed better reflect performance improvements in older adults than $LV_{SLOPE}$.

KEY WORDS: Velocity-based, resistance exercise, geriatric

## INTRODUCTION

The population of older adults (≥ 65 years) in the United States is projected to increase 55% by 2030 and will number 84 million by 2050 (11). Age-associated reductions in muscle size and power manifest in the neuromuscular system (2). Muscle power is reported to improve or maintain physical function and independence more effectively than muscle strength alone (4). However, muscle power declines with age at a faster rate (~10% faster) than muscle strength (3). The neuromuscular adaptations seen with aging - sarcopenia, decrease/changes in type II muscle fibers and motor unit recruitment (leading to a reduction in contraction velocity), and changes to muscle structure (decreases in muscle cross-sectional area, fascicle length, and pennation angle) - contribute to the faster decline in power than in strength (3, 15, 26). Importantly, muscle power is also suggested as a critical component in regaining balance from a slip or trip and avoiding fall-related injuries (2, 12).

Resistance training (RT) interventions have elicited increases in muscle strength and power production, as well as functional ability in older adults (10). Previous research suggests that performing RT at fast velocities elicits greater improvement in muscular power compared to moving heavy loads slowly, in older adults (5, 8, 13, 24, 26-28). Therefore, a fast-velocity approach to RT may *optimally* counteract age-related reductions in neuromuscular function, muscular power, dynamic balance, and improve the ability to react to a sudden trip or slip (4, 7, 10, 15, 17). For example, increases in muscle activation and contractile capacity likely lead to increased movement speed (15), which is especially important when rapid movements are necessary to recover from a balance perturbation and prevent fall-related injuries (25). Therefore, it is *critical* to examine how RT interventions could mitigate the declines in strength (i.e., force) and velocity (i.e., movement speed) associated with age-related muscle loss.

Investigations of the load-velocity (LV) relationship in older adults have gained popularity as a potential method for determining RT prescriptions in various populations (1, 14). The LV relationship is a linear trendline created from multiple trials with increasing load, which provides a snapshot of an individual's speed output while under external resistance. Previous research in older adults has shown an association between the LV relationship and functional ability, and individualizing RT based on the LV relationship was suggested to optimize specific improvements in functional ability, muscle power, and strength by improving whichever variable (i.e., force or velocity) is limiting power production (1). Though one recent study suggests that using the LV relationship as an optimization strategy for RT to improve function and strength was not supported (14), prescribing movement velocity targets as a programming methodology to stimulate adaptations in strength and LV profile characteristics could be key.

Therefore, the purpose of this study was to examine the influence of a fast-velocity RT (FVRT) program compared to a slow-velocity RT (SVRT) program on maximal strength, maximal movement speed, and LV characteristics. We hypothesized that both FVRT and SVRT groups would increase absolute and relative strength, maximal movement speed, and lead to a velocity-specific shift in the slope of the LV relationship following the 8-week RT intervention. Additionally, we hypothesized that the SVRT group would increase strength more than the FVRT group, but the FVRT group would increase maximal movement speed more than the SVRT group.

## METHODS

*Participants*

Nineteen community-dwelling older adults were recruited from the greater Omaha area YMCAs, senior centers, and by word of mouth. Individuals 65 years or older were included in the study if they were able to perform basic physical exercise (i.e., resistance) and activities of daily living (e.g., standing up from a chair, walking, etc.), and were without neuromuscular, circulatory, or edema pathology, lower extremity injury or surgery within the previous six months, or major lower limb surgery (i.e., total knee or total hip replacement). Additionally, participants were excluded from the study if they performed progressive RT within the previous six months. Participants provided written and verbal informed consent and protocols were approved by the university Internal Review Board. This research was carried out in accordance with the ethical standards of the Helsinki Declaration and the International Journal of Exercise Science (16). Participants who met the inclusion criteria were randomly assigned to the FVRT group (n = 10 [f = 7], age = 70.9 ± 6 yrs., height = 167.2 ± 5.7 cm, weight = 69.05 ± 10.6 kg) or the SVRT group (n = 9 [f = 6], age = 74.2 ± 7 yrs., height = 166.7 ± 7.5 cm, weight = 72.73 ± 14.5 kg) and completed eight weeks of RT.

*Protocol*

Prior to any data collection, on the first visit, participants gave informed consent and completed a health history questionnaire. Participants were randomized to either the FVRT or SVRT group. Then, participants completed a familiarization session of the RT exercise (i.e., belt squat) followed by one-repetition maximum (1RM) testing on the belt squat machine, which also generated their baseline LV profile (see Load-Velocity Assessment below). To assess 1RM and the LV profile, participants began the protocol lifting only the rack (31 lbs.), and then the load was increased by 20% of the participant's body weight until they could not safely complete the next repetition (i.e., unable to stand up or maintain balance/form throughout the full movement). Following the failed repetition, 5 kgs were taken off the total amount until a successful lift was completed to ensure accurate 1RM assessment. Two trials at each load were measured, and the highest average velocity trial was retained for processing. Each set was separated by 2-min of rest. Participants completed their respective 8-week RT protocol on the belt-squat machine, consisting of 2 days/week for 8-week (16 sessions) at approximately the same time of day (± 2 hours), separated by 48-96 hours. After the fourth week, 1RM belt squat was re-evaluated to test strength and movement speed. The new 1RM values were used to adjust loads to ensure the RT protocol would progress effectively through the last four weeks of the protocol. The training loads for each of the participants were reassessed because of the known neural adaptations that occur during the first few weeks of RT and to continue to increase the muscular stimuli to promote muscle growth (10). Participants were allowed to miss no more than two non-consecutive training sessions (required adherence ≥ 87.5%) to remain in the study. As such, adherence to the study protocol was 97%.

For the load-velocity assessment, participants performed a short, standardized warm-up (light cycling or walking on a treadmill for 5-min) prior to completing LV profiling via a 1RM belt squat assessment. Specifically, participants were provided a cue of a jack stopping the eccentric part of the squat at ~90° knee flexion. After pausing at the jack, participants were instructed to perform the concentric portion of each repetition "as fast as possible" while maintaining proper technique and safety. Additionally, the load and average concentric velocity achieved during each trial was recorded and used to calculate the slope of each participant's LV profile.

Maximal strength was measured by assessing one repetition maximum ($1RM_{ABS}$) belt squat at baseline (PRE), after four weeks (MID), and after eight weeks (POST) of training. MID $1RM_{ABS}$ testing occurred during the 9th training session (96 hours after the previous training session) and POST $1RM_{ABS}$ testing was assessed 48 hours after the final training session. 1RM is the maximal load (kg) the participant could lift one time with correct technique. Relative 1RM ($1RM_{REL}$) was calculated as the 1RM divided by body weight to normalize each participant's strength relative to their body weight. This normalization to body weight allows for comparison of strength across participants, accounting for differences in body size. Maximal movement speed (MMS; m/s) was determined as the highest mean velocity achieved when lifting the empty belt squat rack (31 lbs.). The MMS for all participants occurred during the empty rack trials. The empty belt squat rack was used as the standard load for PRE, MID, POST testing sessions. The highest mean velocity trial at each submaximal load was used to create a linear regression equation. The slope of the linear regression equation ($LV_{SLOPE}$) was calculated to assess belt squat performance as it related to the interaction between load and velocity. The area under the LV regression line ($LV_{AREA}$) was calculated using the trapezoidal method.

When designing a RT protocol for older adults, selection of exercises that mimic functional movements (i.e., movement patterns required during everyday life) is essential for maximizing benefits (12). The belt squat was chosen because of its specificity to rising from a seated position (e.g., chair, toilet, vehicle), as well as the safety inherent to load application at the hips rather than across the back and shoulders (i.e., a traditional barbell back squat). Participants in both groups completed sets of five repetitions of the belt squat followed by a rest period until they reached their prescribed volume for each training session (2 days/week separated by at least 48 hr.) to limit fatigue and support inter-session recovery.

Training volume for each group was calculated as repetitions × load for each session. The FVRT group was prescribed progressive repetitions (20, 25, 30, 25, 25, 30, 35, and 30) for each session throughout the eight weeks. The repetition totals were chosen based on the suggested resistance training prescription for older adults, which recommends 12-36 repetitions (2-3 sets of 6-12 repetitions) per training session with 2-3 training sessions per week for each muscle group (10). The SVRT group performed fewer repetitions at a slower velocity (0.25 m/s), but with greater loads compared to the FVRT group (more repetitions at a faster velocity (0.70 m/s), but with lighter loads). To equate training volume, a linear regression equation of system mass with respect to average velocity was used to estimate the external load required to produce 0.7 m/s or 0.25 m/s for the FVRT and SVRT groups, respectively. These loads were used to calculate the number of repetitions needed to match training volume between the SVRT and FVRT groups. Therefore, the training volume for the SVRT group was dependent on the calculated volume *if* that participant had been randomly assigned to the FVRT group. Previous research has not determined velocity ranges for power or strength training in older adults. However, the velocity thresholds were chosen due to the recommendation of fast and slow velocity contractions that can elicit either power focused outcomes or maximal strength outcomes (23).

FVRT and SVRT groups were instructed to move the weight "as fast as possible" during the concentric phase of the movement and received instantaneous visual feedback of their movement velocity from a linear position transducer (Tendo power analyzer, Tendo Sport Machines, London, UK) and verbal encouragement to ensure concentric movement was within their target movement velocity zone. Participants completed sets of 5 repetitions with 2 min of rest between sets until the prescribed number of repetitions was completed for each session. If the velocity for a repetition was below the prescribed velocity zone before 5 repetitions were completed, the set was stopped, and the participant began a 2-min rest period before attempting again. The load was adjusted (i.e., increase load if movement velocity was faster than target and reduce load if moving slower than prescribed target) if the participant's movement velocity was outside of the prescribed movement range for 3-5 repetitions. Participants were allowed to use as many sets as necessary to complete the required repetitions. Total volume (kg/repetition) was assessed following each session and summed at the end of the 8-weeks of resistance training. The average total volume was the average of the individual groups total volume following 8-weeks of resistance training.

*Statistical Analysis*

An a priori power analysis indicated that 19 subjects would exceed 80% power for detecting an effect size of $f^2 = 0.65$ for relevant differences at an alpha < 0.05 (6). Bayesian generalized linear models with Markov Chain Monte Carlo (MCMC) estimation via the *MCMCglmm* package in R (version 4.2.2) were used to investigate changes in dependent variables. Time and group assignment were modeled as fixed effects. Normality of data was verified using the D'Agostino–Pearson test, and a non-informative, uniform prior was used for all analyses. Reported parameter estimates include the posterior mean difference (expected difference in the specific variable between either group or timepoint) and the 95% credible intervals (CI; range of values that would be expected to contain the posterior mean difference). Effect size estimates were calculated by using Hedge's *g*. Parameter estimates were interpreted as statistically significant if the 95% CI did not include zero. Significant interaction effects were analyzed using analysis of simple effects.

## RESULTS

*Absolute and Relative Strength*

The results should be reported in a logical sequence, giving the main findings first. The use of $1RM_{ABS}$ had no interaction effect. However, a main effect for time was observed, indicating that POST was significantly greater than PRE (posterior $mean_{diff}$: 41.06 kg, 95% CI: 21.85 – 58.7) (Figure 1). Post-hoc analyses suggested the SVRT group had an average $1RM_{ABS}$ increase of 46.6 ± 23.6 kg (*g* = 0.94; 96.1% probability of improvement) from PRE to POST whereas the FVRT group had an average increase of 36.4 ± 3.62 kg (*g* = 1.53; 99.7% probability of improvement).

A significant interaction effect was observed for increases in $1RM_{REL}$ strength across groups. Specifically, SVRT had significantly larger increases at each time point (MID: posterior $mean_{diff}$: 0.3 kg/BW, 95% CI: 0.06 - 0.51; POST: posterior $mean_{diff}$: 0.31 kg/BW, 95% CI: 0.07 – 0.53) relative to FVRT (Figure 2). Post-hoc analyses suggest the SVRT group had an average increase of 0.82 ± 0.1 kg/BW (*g* = 1.43; 99.5% probability of improvement) from PRE to POST whereas the FVRT group had an average increase of 0.51 ± 0.06 kg/BW ($g$ = 1.37; 99.4% probability of improvement). However, this is likely due to the significant group difference at PRE (Figure 2).

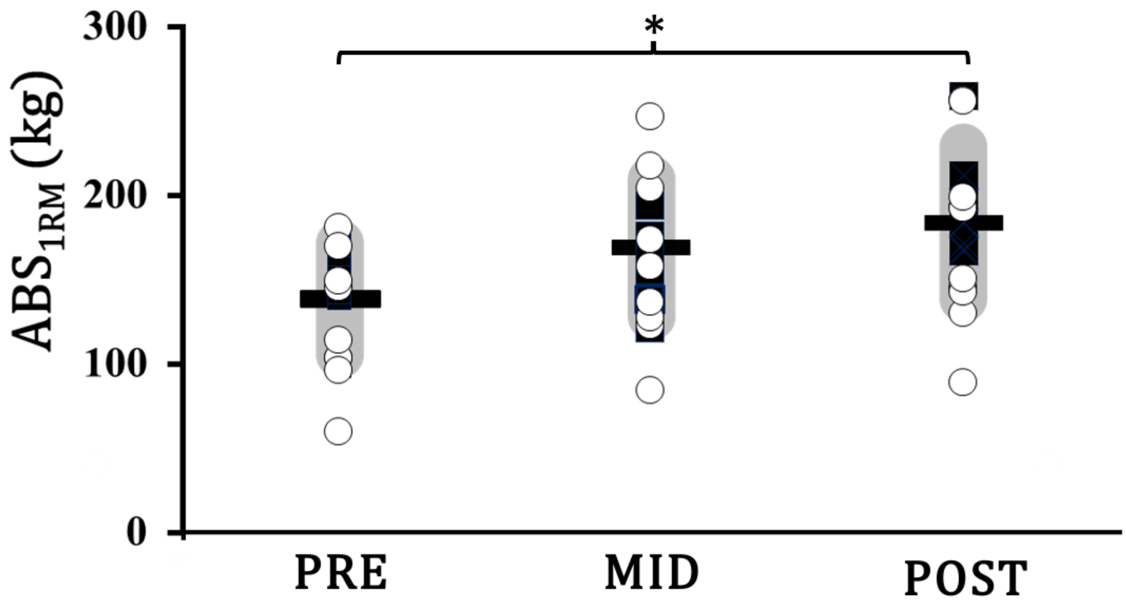


**Figure 1.** Difference in $1RM_{ABS}$ from Pre, MID, and POST. Black squares represent FVRT group and white circles represent SVRT group. * = Significant increase from PRE. Solid black line indicates mean. Vertical gray bars behind the data points indicate standard deviation.

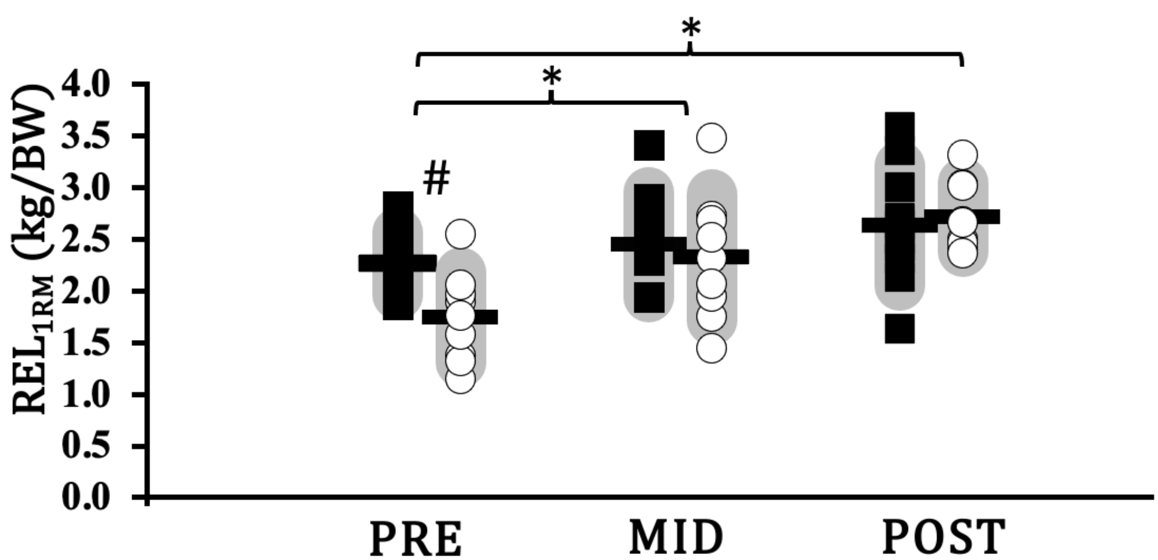


**Figure 2.** Difference in $REL_{1RM}$ from Pre, MID, and POST. Black squares represent FVRT group and white circles represent SVRT group. * = Significant increase from PRE for SVRT group. # = Significant difference between groups. Solid black line indicates mean. Vertical gray bars behind the data points indicate standard deviation.

*Maximal Movement Speed*
There was no interaction effect for MMS, but there was a main effect for time. Post-hoc tests indicate that POST-MMS was significantly greater than PRE (posterior $mean_{diff}$: 0.08 m·s$^{-1}$, 95% CI: 0.03 – 0.13) (Figure 3). We also observed a main effect for group, as SVRT moved significantly slower at all time points (posterior $mean_{diff}$: -0.25 m·s$^{-1}$, 95% CI: -0.42 – -0.1). Post-hoc analyses suggest that SVRT MMS increased an average of 0.1 ± 0.06 m·s$^{-1}$ (*g* = 0.44; 79.9% probability of improvement) from PRE to POST whereas the FVRT increased an average of 0.09 ± 0.03 m·s$^{-1}$ (*g* = 0.78; 93% probability of improvement).

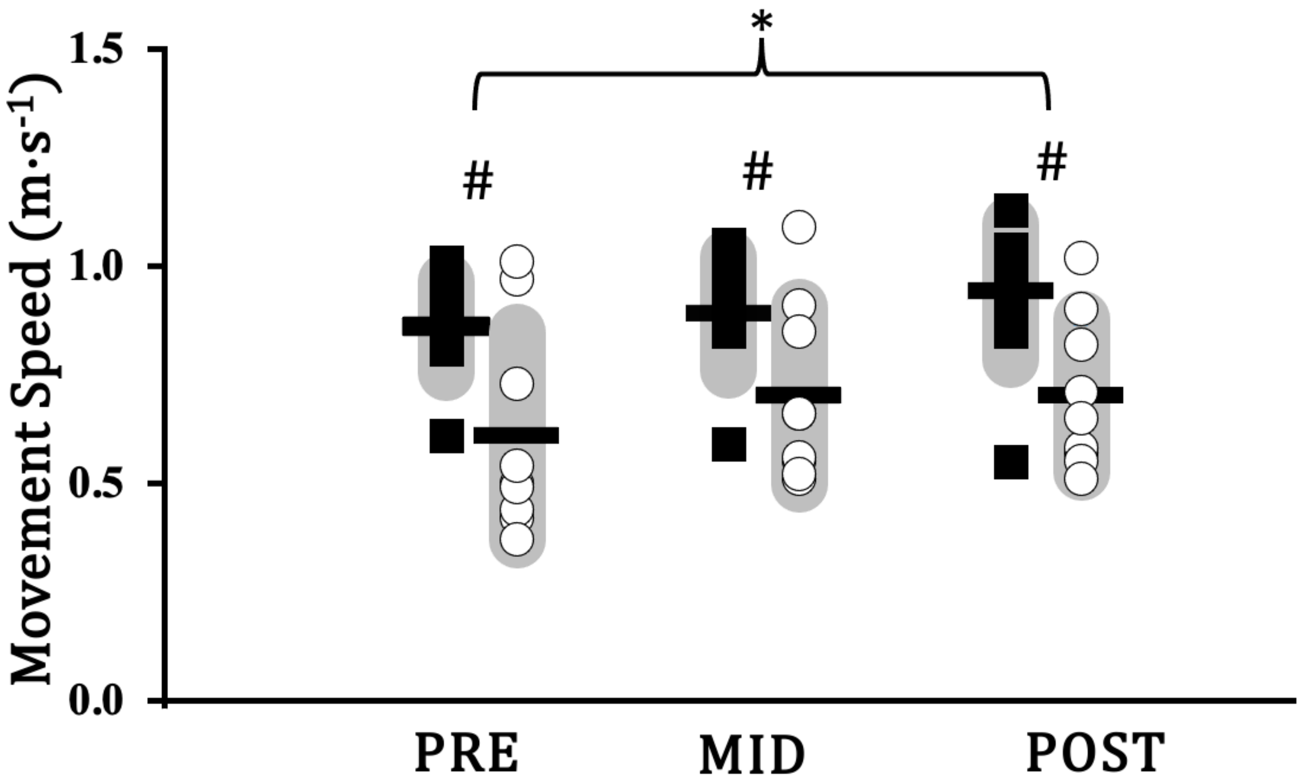


**Figure 3.** Difference in maximal movement speed (MMS) within each group from PRE, MID, and POST for FVRT (black squares) and SVRT (white circles). * = Significant increase from PRE. # = Significant difference between groups. Solid black line indicates mean. Vertical gray bars behind the data points indicate standard deviation.

*Load-Velocity Slope and Area Under the Load-Velocity Regression Line*
There were no interaction effects or main effects of $LV_{SLOPE}$ for time. However, a main effect for group was observed with SVRT exhibiting a greater negative slope than FVRT (posterior $mean_{diff}$: 0.19, 95% CI: 0.03 – 0.38) (Figure 4).

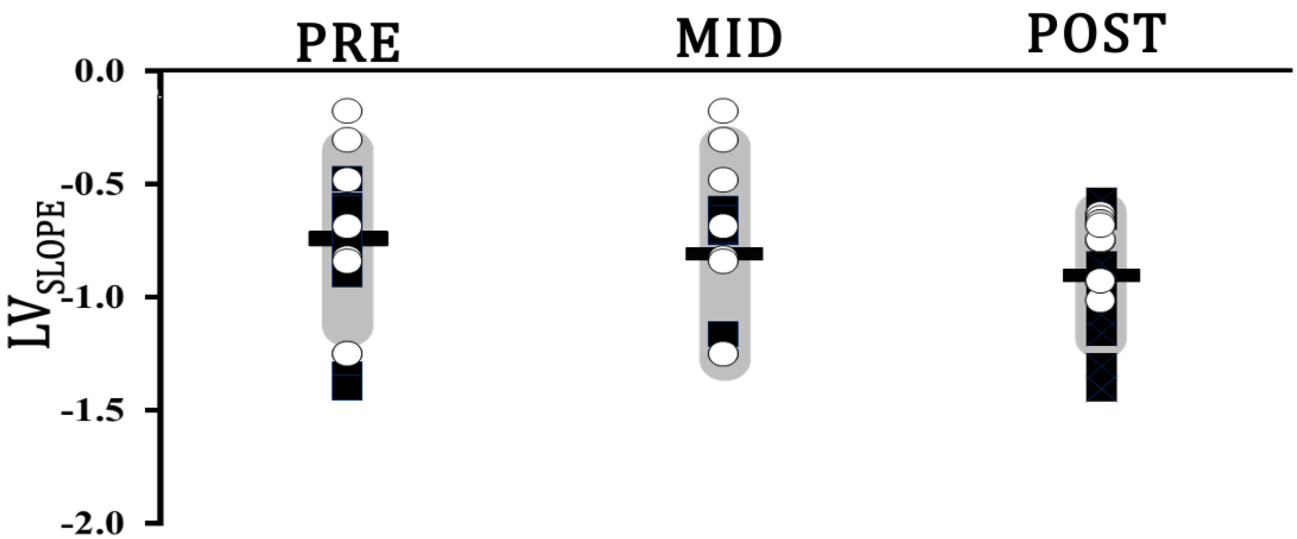


**Figure 4.** Difference in $LV_{SLOPE}$ across time. Solid black squares indicate participants in the FVRT group. White circles indicate participants in the SVRT group. * = Significant increase from PRE. Solid black line indicates mean. Vertical gray bars behind the data points indicate standard deviation.

There was no interaction effect for $LV_{AREA}$, but there was a main effect for time. Both MID and POST $LV_{AREA}$ were significantly larger than PRE (MID posterior $mean_{diff}$: 0.24, 95% CI: 0.13 – 0.35; POST posterior $mean_{diff}$: 0.39, 95% CI: 0.27 – 0.49) (Figure 5, 6). Post-hoc analyses suggest SVRT $LV_{AREA}$ increased 0.36 ± .09 ($g$ = 1.13; 98.3% probability of improvement) from PRE to POST, whereas FVRT $LV_{AREA}$ increased and average of 0.39 ± 0.02 ($g$ = 1.63; 99.9% probability of improvement).

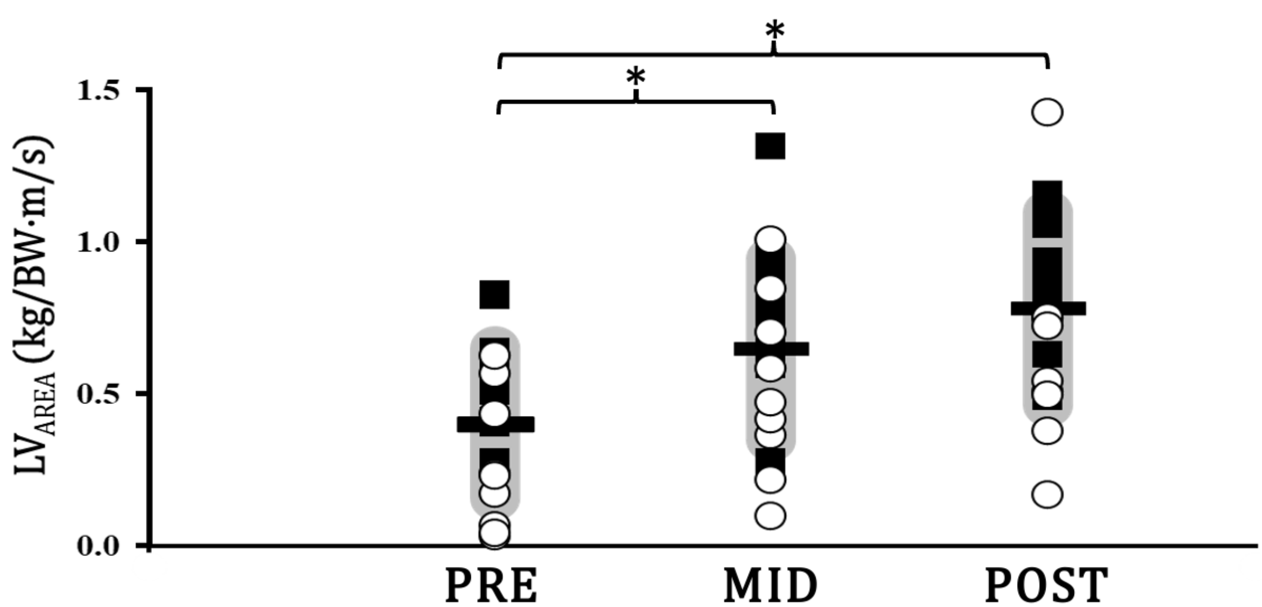


**Figure 5.** Difference in $LV_{AREA}$ at each time point collapsed across groups. Solid black squares indicate participants in the FVRT group. White circles indicate participants in the SVRT group. * = Significant increase from PRE. Solid black line indicates mean. Vertical gray bars behind the data points indicate standard deviation.

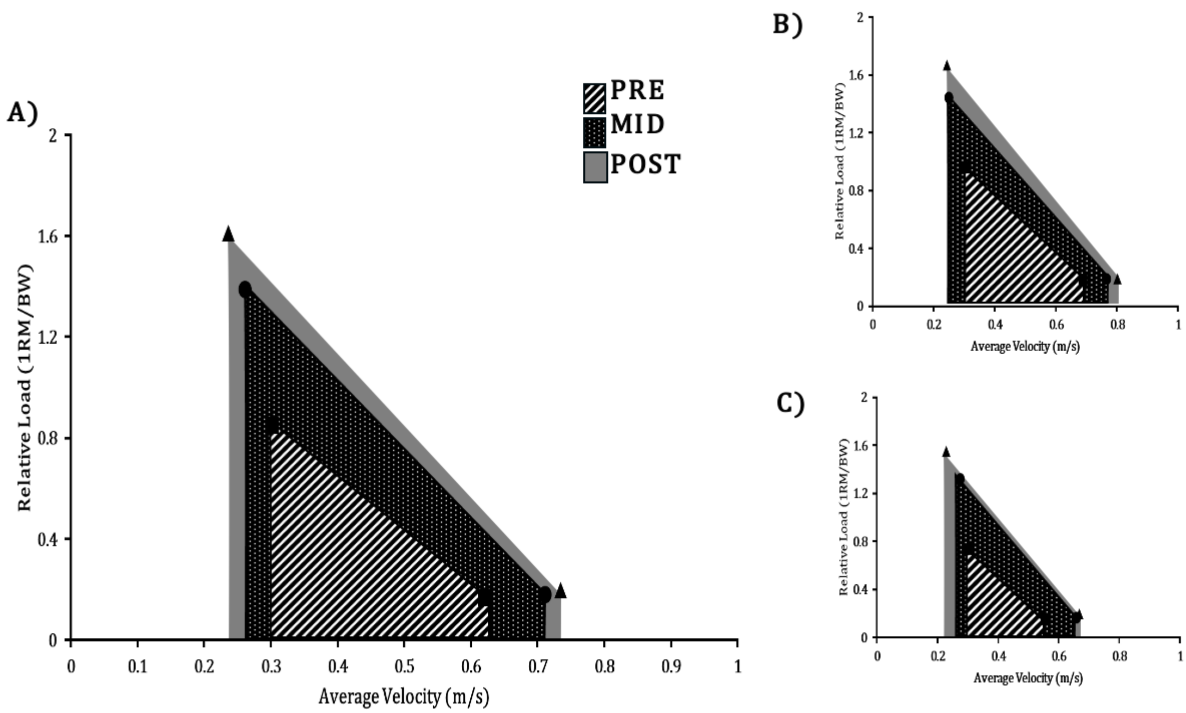


**Figure 6.** Graphical illustration of the $LV_{SLOPE}$, and $LV_{AREA}$ from PRE-, MID-, and POST-intervention for A) all participants (FVRT and SVRT collapsed) B) FVRT and C) SVRT groups. MID and POST $LV_{AREA}$ measures were greater than PRE. $LV_{SLOPE}$ were not different between any timepoint.

*Average Total Volume*

Although the SVRT group lifted a higher absolute load per repetition during each session compared to the FVRT group, there was no difference in average total volume between groups (FVRT: 47490.3 ± 10888.3 kg/session; SVRT: 44679.3 ± 15250.9 kg/session, $p = 0.26$, $g = 0.60$) (Figure 7). Over the course of the study, only 2% of RT sessions were missed.

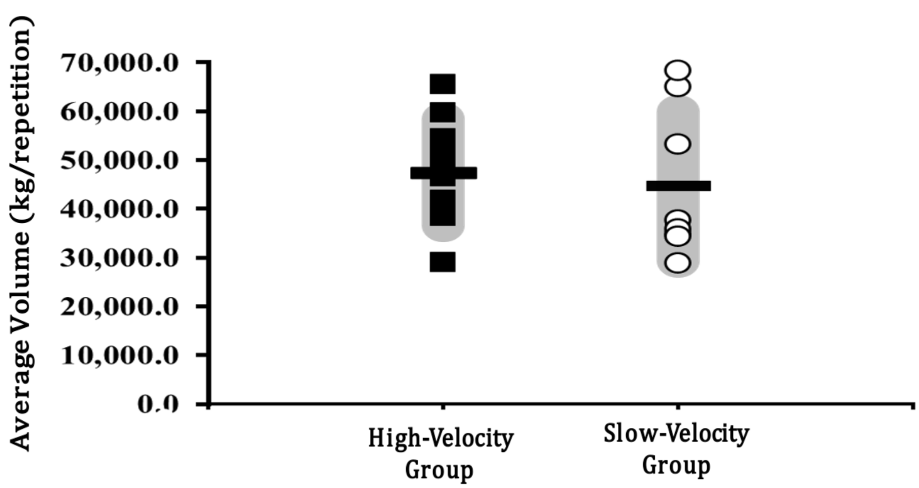


**Figure 7.** Average total volume ratio (kg/repetitions) completed for each group. Solid black line indicates mean. Vertical gray bars behind the data points indicate standard deviation.

**DISCUSSION**

Previous research suggests that older adults may suffer from a reduction in force or velocity generating capacity which may influence the LV relationship (1). As a result, there is an emerging body of literature describing the effect of targeted RT methodologies to improve deficits in velocity- or force- generating capacities to influence the LV relationship and functional capacity in older adults (1, 5, 14, 18, 20, 22). Our findings suggest that, when total RT volume is matched between groups of older adults, both FVRT and SVRT RT can increase strength (i.e., $ABS_{1RM}$ and $REL_{1RM}$), movement speed, and $LV_{AREA}$. A novel finding in the study is the significant increase in $LV_{AREA}$, 1RM, and MMS, with a non-significant change in $LV_{SLOPE}$. These data suggest that maximal strength, movement speed, and/or $LV_{AREA}$ are better indicators of performance adaptations than $LV_{SLOPE}$ alone. In contrast, a nonsignificant change in $LV_{SLOPE}$ suggests the sensitivity and utility of the $LV_{SLOPE}$ is limited regarding prescription or assessment of resistance training and performance in older adults over an 8-week period.

Improvements in strength ($1RM_{ABS}$ and $1RM_{REL}$) from PRE to POST in FVRT and SVRT groups align with the body of literature which suggests that RT improves muscle strength regardless of load when emphasis is placed on the *intent* to move the load quickly (13, 19, 22, 27, 29). Recently, others have also reported SVRT and FVRT interventions improved maximal strength in the older adult population, though SVRT RT resulted in greater strength adaptations compared to FVRT RT (21, 29). Our data suggests the SVRT group increased absolute strength more than the FVRT group (SVRT = ~46.6 kg vs. ~36.4 kg); however, there was no significant difference in muscle strength between groups following the two RT protocols. Although training volume was matched between groups for our study, the difference in strength adaptations is likely due to the increased absolute load in the SVRT group compared to the FVRT group (14). One study reported increased load lifted at a slow velocity provided the targeted muscles increased time under tension, which likely led to greater strength improvements in SVRT compared to FVRT (14). These data suggest that both SVRT with heavy load and FVRT with lighter loads elicit similar strength adaptations in older adults (22).

The $LV_{SLOPE}$ was not significantly different at any time point; however, the $LV_{AREA}$ was significantly larger at MID and POST compared to PRE. Therefore, assessment of 1RM, MMS, and ultimately $LV_{AREA}$ may be a better indicator of RT adaptations than $LV_{SLOPE}$ in the older adult population. The LV relationship provides information about the tradeoff between strength and movement speed. A steeper negative slope indicates an increase in strength and a reduction in movement velocity. A flatter slope indicates an increase in movement velocity and a reduction in strength. Slope changes are dependent on the improvement of a single variable (i.e., 1RM or MMS), whereas a change in area under the line would indicate improvements in or worsening of both 1RM and MMS. An improvement in both variables would result in a rightward shift of the LV regression line, no changes in steepness of the regression slope, and increased area under the line (the length of the regression line). The area under the line serves as a quantifiable measure to describe changes in either the 1RM or the MMS variables without examining the steepness of the load velocity slope. This result is supported by the results of Lindberg et al. (14) who suggest a shift in the LV relationship indicates increased power output that results in increased performance in power-dependent movements in older adults (i.e., sit-to-stand, stair climbing, recovering from a slip/trip). A change in the steepness of the slope of the LV relationship may improve or reduce physical function in activities of daily living depending on the specific variable needed to complete the movement (14). Our data, in combination with Lindberg et al. (14), suggests that RT at any load can lead to an upward and rightward shift in the LV profile, further questioning the utility of $LV_{SLOPE}$ as a variable for prescribing RT for untrained older adults.

The study is not without limitations; however, further investigation is warranted. The greatest limitation was the sample size. Additionally, our study matched RT volume (reps*kg), but not muscular work or time under tension. This limitation could be the driving factor for the similar performance in muscular strength outcomes between groups in the current study. It is possible that muscular work or time under tension could be greater in the SVRT group compared to the FVRT group, potentially providing an amplified stimulus for strength adaptation. However, calculating work or time under tension in a practical setting is difficult and would be hard to implement in the field or clinic. Note that the results of the current study show that both groups improved strength and movement speed similarly. The SVRT group was slower at all timepoints which dampened our ability to assess if the FVRT group increased in MMS compared to the SVRT group. Further investigation with larger sample sizes should be completed before generalizing our results to all older adults, as MMS increased in both groups following the training protocol. Finally, training status could have impacted the results of the current study and should be considered in future studies.

The results of the current study suggest similar performance adaptations in older adults can be elicited by FVRT and SVRT to gain muscle strength and improve movement speed. Further, the increased $LV_{AREA}$, $1RM_{REL}$, and MMS with no observed change in $LV_{SLOPE}$ suggests that $LV_{AREA}$, $1RM_{REL}$, and MMS are better indicators of performance improvements following a training intervention than assessing steepness of the $LV_{SLOPE}$ in older adults. Future work should continue to expand the evidence for the specific prescription of velocity-based RT with older adults to best improve physical function in older adults.

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**REFERENCES**

1. Alcazar J, Rodriguez-Lopez C, Ara I. Force-velocity profiling in older adults: An adequate tool for the management of functional trajectories with aging. Exp Gerontol 108: 1-6, 2018.

2. Benichou O, Lord S. Rationale for strengthening muscle to prevent falls and fractures: A review of the evidence. Calcif Tissue Int 98(6): 531-545, 2016.

3. Brady A, Straight C, Evans E. Body composition, muscle capacity, and physical function in older adults: An integrated conceptual model. J Aging Phys Act 22(3): 441-452, 2014.

4. Byrne C, Faure C, Keene D, Lamb S. Ageing, muscle power and physical function: A systematic review and implications for pragmatic training interventions. Sports Med 46(9): 1311-1332, 2016.

5. Cadore E, Pinto R, Reischak-Oliveira Á, Izquierdo M. Explosive type of contractions should not be avoided during resistance training in elderly. Exp Gerontol 102: 81-83, 2018.

6. Cohen, J. A power primer. Psycol Bull 112(1): 155-159, 1992.

7. Cruz-Jentoft A, Bahat G, Bauer J. Sarcopenia: Revised european consensus on definition and diagnosis. Age Ageing 48(1): 16-31, 2019.

8. Englund D, Sharp R, Selsby J, Ganesan S, Franke W. Resistance training performed at distinct angular velocities elicits velocity-specific alterations in muscle strength and mobility status in older adults. Exp Gerontol 91: 51-56, 2017.

9. Florence C, Bergen G, Atherly A, Burns E, Stevens J, Drake C. Medical costs of fatal and nonfatal falls in older adults. J Am Geriatr Soc 66(4): 693-698, 2018.

10. Fragala M, Cadore EL, Dorgo S. Resistance training for older adults: Position statement from the national strength and conditioning association. J Strength Cond Res 33(8): 2019-2052, 2019.

11. Haddad Y, Bergen G, Florence C. Estimating the economic burden related to older adult falls by state. J Public Health Manag Pract 25(2): E17-E24, 2019.

12. Han L, Yang F. Strength or power, which is more important to prevent slip-related falls? Hum Mov Sci 44: 192-200, 2015.

13. Hester G, Pope Z, Magrini M. Age does not attenuate maximal velocity adaptations in the ipsilateral and contralateral limbs during unilateral resistance training. J Aging Phys Act 27(1): 1-8, 2019.

14. Lindberg K, Lohne-Seiler H, Fosstveit S. Effectiveness of individualized training based on force–velocity profiling on physical function in older men. Scand J Med Sci Sports 32(6): 1013-1025, 2022

15. McKinnon N, Connelly D, Rice C, Hunter S, Doherty T. Neuromuscular contributions to the age-related reduction in muscle power: Mechanisms and potential role of high velocity power training. Ageing Res Rev 35: 147-154, 2017.

16. Navalta J, Stone W, Lyons T. Ethical issues relating to scientific discovery in exercise science. Int J Exerc Sci 12(1): 1-8, 2019.

17. Pamukoff D, Haakonssen E, Zaccaria J, Madigan M, Miller M, Marsh A. The effects of strength and power training on single-step balance recovery in older adults: A preliminary study. Clin Interv Aging 9: 697-704, 2014.

18. Ramirez-Campillo R, Alvarez C, Garcìa-Hermoso A. High-speed resistance training in elderly women: Effects of cluster training sets on functional performance and quality of life. Exp Gerontol 110: 216-222, 2018.

19. Reid K, Martin K, Doros G. Comparative effects of light or heavy resistance power training for improving lower extremity power and physical performance in mobility-limited older adults. J Gerontol A Biol Sci Med Sci 70(3): 374-380, 2015.

20. Richardson D, Duncan M, Jimenez A, Juris P, Clarke N. Effects of movement velocity and training frequency of resistance exercise on functional performance in older adults: A randomised controlled trial. Eur J Sport Sci 19(2): 234-246, 2019.

21. Rodriguez-Lopez C, Alcazar J, Sanchez-Martin C. Neuromuscular adaptations after 12 weeks of light-vs. heavy-load power-oriented resistance training in older adults. Scand J Med Sci Sports 32(2): 324-337, 2022.

22. Rosa Orssatto L, de la Rocha Freitas C, Shield A, Pinto R, Trajano G. Effects of resistance training concentric velocity on older adults' functional capacity: A systematic review and meta-analysis of randomised trials. Exp Gerontol 127: 110731, 2019.

23. Rosa Orssatto L, Cadore E, Andersen L, Diefenthaeler F. Why fast velocity resistance training should be prioritized for elderly people. Strengh Cond J 41 (1): 105-114, 2019.

24. Sayers S, Gibson K, Bryan Mann J. Improvement in functional performance with high-speed power training in older adults is optimized in those with the highest training velocity. Eur J Appl Physiol 116 (11-12): 2327-2336, 2016.

25. Sayers S, Gibson K. Effects of high-speed power training on muscle performance and braking speed in older adults. J Aging Res 2012: 426278, 2012.

26. Schaun G, Bamman M, Alberton C. High-velocity resistance training as a tool to improve functional performance and muscle power in older adults. Exp Gerontol 156: 111593, 2021.

27. Straight C, Lindheimer J, Brady A, Dishman R, Evans E. Effects of resistance training on lower-extremity muscle power in middle-aged and older adults: A systematic review and meta-analysis of randomized controlled trials. Sports Med 46(3): 353-364, 2016.

28. Tschopp M, Sattelmayer M, Hilfiker R. Is power training or conventional resistance training better for function in elderly persons? A meta-analysis. Age Ageing 40(5): 549-556, 2011.

29. Vieira I, Lobo P, Fisher J, Ramirez-Campilo R, Pimentel G, Gentil P. Effects of high-speed versus traditional resistance training in older adults. Sports Health 14(2): 283-291, 2022.