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Effects of Power on Balance and Fall Prevention in Aging and Older Adults

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Falls are a common health issue among older adults. Muscle weakness, limited physical function, and balance impairment have been identified as the modifiable risk factors for falls. The purpose of this review is to analyze current evidence about the efficacy of power training in improving physical function, improving balance, and preventing falls in older adults. We also provide recommendations regarding power training protocols for older adults. This review suggests that power training is effective in reducing several risk factors for falls. Future interdisciplinary studies are needed to provide evidence about how to incorporate power training in a fall prevention program.

Key words: falls, frail elderly, high-velocity resistance training, physical function performance, postural balance

Falls are a major health issue. Worldwide, more than 646 000 individuals die as a result of falling each year, with the greatest rate of fatal falls occurring among adults older than 65 years.[1] Approximately $50 billion is spent on medical costs related to fatal and nonfatal fall injuries each year.[2] Muscle weakness, limited physical function, and balance impairment have been identified as the primary intrinsic factors for falls.[3,4] Consequently, strengthening and balance exercises have been shown to be effective in reducing these intrinsic risk factors.[5,6] A study published by Gschwind et al[4] demonstrated the potential benefits of a combination of balance and strengthening exercises in older adults who are at high risk of falls.

Recently, several clinical trials examined the effectiveness of power training, in particular, on functional limitations and balance impairment to reduce risks and incidences of falls. Power training has been shown to cause physiological changes in muscle morphology and neuromuscular and neurosensory systems for older adults. Age-related muscle weakness is caused not only by decreasing muscle mass but also by an increasing amount of intramuscular adipose tissue that interferes with the ability to generate muscle force.[7-9] As muscle tissues age, type II fibers decrease because of irreversible denervation or denervation, followed by reinnervation with type I motor neurons. In addition, the number of active motor units decreases. These neuromuscular changes limit the ability for an older adult to generate higher muscle forces in velocity-sensitive manners. This muscle power dysfunction can lead to limited physical function and impaired balance.[10,11] Moreover, age-related changes in the afferent sensory system, such as decreased vision, vestibular sense, reaction time, and proprioception, contribute to balance disorders and risks of fall.[12-14] To counteract these changes, power training (sometimes called "high-velocity resistance training") aims to reeducate the remaining functional elements and stimulate new adaptations in the aging neuromuscular-sensory system. Power training attempts to achieve this through rapid movements with alternative concentric and eccentric contractions.[15] Consequently, power training has been used as a time-efficient and beneficial therapeutic intervention to improve physical function, muscle strength, and balance ability.

While many power training studies have reported a positive training effect using physical performance measures,[16-24] only a few studies have examined the specific effects of power training on dynamic balance performance. Furthermore, although there may be an association between muscle weakness and falls, there is currently limited evidence that power training reduces the incidence of falling in older adults. Finally, there are still questions about safety and feasibility of power training in older adults due to the possible adverse effects associated with power training, such as the early onset of fatigue and delayed onset muscle soreness.[25] The purpose of this narrative review is to analyze current evidence regarding the efficacy of high-velocity power training in improving physical function, improving balance performance, and reducing fall incidences in older adults. In addition, we examine the protocols used in previous experimental interventions to provide insights for designing optimal power training protocols for older adults.

MAIN ANALYSIS

Muscle power and physical function in older adults

Muscle power has been found to be a stronger independent predictor of functional performance than muscle

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strength in older adults.[26-29] More specifically, peak muscle power of the leg extensors[27] and ankle plantar flexors[29] was identified as 2 significant predictors of functional performance. Furthermore, a study by Cuoco and colleagues[28] evaluated the relationship between muscle power output at different contraction velocities and 3 functional tasks in 48 men and women aged 65 to 91 years. The muscle power output was measured under the following intensities: 40%, 50%, 60%, 70%, 80%, and 90% of 1 repetition maximum (1 RM). The 3 functional tasks included were walking speed, stair-climbing time, and chair rise time. They found that lower extremity muscle power measured at 70% 1 RM and 40% 1 RM explained a greater proportion of the variability in all 3 functional tasks than did 1 RM strength.[28] Moreover, power measured at 40% 1 RM explained a greater proportion of the variability in walking speed than did power measured at 70% 1 RM.

The velocity component of muscle contraction was found to be a critical determinant of the age-related decline in muscle power in older adults.[30,31] These research findings suggest that how quickly older adults can move might be more important in preserving physical function than how strong the muscles are. Crossing an intersection with sufficient speed is an activity that requires muscle power. An older adult may not be able to make it across the intersection without being able to generate lower extremity force quickly. Also, the ability to generate fast and sufficient movement to recover from a loss of balance is critical to prevent a fall and related injuries. As a result, one would expect power training emphasizing movement at higher velocities to be clinically important in improving physical function and balance performance, as well as reducing fall incidences in older adults.

Effects of power training on physical function in older adults

Several systematic reviews[11,15,32-36] and randomized controlled trials[16-24] have examined the effect of power training interventions on physical function in older adults. Most of these randomized controlled trials included conventional low-velocity resistance training as the control intervention.

Henwood et al[24] compared the effect of high-velocity varied resistance training with low-velocity constant resistance training on physical function in independent older adults. In this study, physical function was evaluated using a battery of 8 physical performance tests. These tests included (1) floor rise to standing, (2) stair climb, (3) typical, fast, and backward walking speed over 6 m, (4) the Five Times Sit to Stand test, (5) 400-m walk, and (6) the Functional Reach test. They found that both interventions showed similar improvements in all physical performance measures after a 24-week intervention. Similarly, Drey et al[19] conducted a randomized controlled trial comparing the effects of power training and strength training on physical performance for prefrail community-dwelling older adults. Physical performance was measured by the Short Physical Performance Battery. Although both training methods demonstrated significant improvements in the Short Physical Performance Battery after a 12-week training program, no differences were found in the improvements between power training and strength training. On the contrary, Miszko et al[17] reported that power training demonstrated a greater improvement in physical function than strength training. In this study, physical function was measured using the Continuous Scale Physical Functional Performance test (CS-PFP), which consists of a battery of 16 daily tasks in 5 domains: lower body strength, upper body strength, upper body flexibility, balance and coordination, and endurance. The strength training group performed upper and lower body exercises at 80% 1 RM while the power training group trained at 40% 1 RM with the concentric component being completed as fast as possible. Participants in both groups met 3 days per week for 16 weeks. After the training, the power training group demonstrated a significantly greater CS-PFP total score than the strength training group. Similarly, Bottaro et al[37] reported that power training may be superior to strength training for improving physical function. They found that a 10-week high-velocity resistance training significantly improved 30-Second Sit to Stand and 8-Foot Up and Go performance while conventional low-velocity resistance training did not demonstrate such an improvement.

Most of the power training studies utilized free-weight and machine exercises as the training modalities.[17,22,24] Considering that most older adults do not have access to weight training equipment at gyms, Bean et al[20] applied weighted vests for power training during functional mobility tasks, such as chair stands, toe raises, pelvic raises, step-ups, seated triceps dips, and chest press. In this training protocol, called InVEST (Increased Velocity Exercises Specific to Task), participants were asked to perform the concentric component of the functional tasks as quickly as possible while maintaining good form. The InVEST group demonstrated significant improvements in walking speed and single-leg stance time after the 12-week training. In contrast, the control group, that performed low-velocity strength training, showed no significant improvement in these 2 outcomes.

In addition, 3 systematic reviews, Hazell et al,[36] Tschopp et al,[35] and Reid et al,[11] assessed and summarized the results from several primary studies that examined the effects of power training compared with conventional low-velocity resistance training in older adults. These reviews also support the conclusion that power training can be more effective than strength training in improving physical function.

Effects of power training on balance in older adults

Most power training studies to date have used physical performance measures to demonstrate the effects of training. Balance control is an important component of physical function; however, very few studies have specifically examined the effects of power training on dynamic balance performance.

Balance was included as one of the secondary outcomes in a meta-analysis systematic review that compared the effects of power training and strength training on functional performance.[35] The clinical balance outcome measures included in this review were the Functional Reach test, balance domain of the CS-PFP, and single-leg stance time. The authors concluded that there is little evidence for a moderate to large effect of power training on balance compared with strength training (95% confidence interval: 0.17-1.99, $P = .098$, $I^2 = 80.7\%$).

Two studies used biomechanical balance parameters to evaluate the effects of power training. Orr et al[38] examined the effects of a 10-week high-velocity power training (2 sessions per week) on balance performance. Balance was assessed under 3 conditions on a computerized platform: (1) narrow bilateral stance on a platform sliding forward then backward; (2) narrow bilateral stance on a platform tilting up and down; and (3) unilateral stance of the preferred leg on a still platform with eyes open and closed. Body sway and the number of balance losses were recorded as a measure of balance performance. High-velocity power training was found to significantly improve the balance performance for healthy community-dwelling older adults as compared with a nontraining control group. In addition, low-intensity power training at 20% 1 RM resulted in the greatest improvements in balance performance when compared with power training at higher intensity (50% 1 RM and 80% 1 RM.)

Pamukoff et al[39] also conducted a study using biomechanical balance parameters to compare the effects of 6-week (3 sessions per week) power training and strength training programs. Balance was assessed using maximum forward and lateral lean angle measured during a forward and lateral single-step balance recovery task. Although significant improvements were found in balance recovery performance when combining results from both groups, power training did not demonstrate a larger improvement than strength training. The authors noted that the lack of significant group differences could be due to the small sample size (20 participants) and the short training duration. In summary, these 2 studies provide evidence that power training can improve balance performance as measured by biomechanical balance parameters. However, more research is required to investigate whether power or strength training is more effective and the optimal duration for training.

Effects of power training on fall prevention in older adults

Muscle weakness is considered to be one of the modifiable risk factors for falls in older adults.[40,41] In a recent study of older women, the combination of poor lower limb muscle power and asymmetry between limbs was found to be more predictive of future falls than traditional measurements of strength.[42] Although there may be an association between muscle power and falls, more studies are needed to investigate whether power training is effective in preventing falls in older adults.

Gianoudis et al[43] implemented a multimodal fall prevention exercise program that included high-velocity power training with diverse-loading weight-bearing exercises and high-challenge balance/functional exercises. Participants were required to perform the weight-bearing exercises with rapid concentric movements. The authors found that this multimodal exercise program improved functional performance in older adults with higher fall risk. However, this improvement did not lead to a reduction in fall rate. Currently, there is limited evidence of effectiveness on the impact of power training interventions on fall reduction. Until more study results are published, uncertainty will remain about the benefit of adding power training to a fall prevention program for community-dwelling older adults.

Power training for older adults living with frailty

Older adults living with frailty are especially in need of improving their functional capacities to prevent negative consequences of falls, such as hospitalization, disability, or death. Studying nonagenarians residing in an institution, Cadore et al[44] found that a 12-week multicomponent exercise program that included high-velocity power training improved muscle strength, power, and cross-sectional area, as well as physical function (30-Second Sit to Stand test) and balance (single- and dual-task Timed Up and Go test). In addition, fall incidences were significantly lower in the intervention group than in the control group that received range-of-motion exercises. In this randomized controlled trial, resistance training was performed using resistance variable machines with progressively increased loads that optimized muscle power output (8-10 repetitions, 40%-60% 1 RM).

Reid et al[22] investigated the effects of power training in older adults aged 70 to 85 years with limited mobility. They found that low-resistance (40% 1 RM) power training yielded significant but similar improvements in physical performance when compared with high external resistance (70% 1 RM).[22] Finally, a recent review conducted by Izquierdo and Cadore[45] concluded that including power training in a multicomponent fall prevention exercise program is a beneficial and safe intervention to prevent functional limitation and subsequent disability for older adults who are frail.

The results of these studies indicate that power training is a feasible and safe intervention to improve physical function in older adults living with frailty. Although no injuries or adverse training effects were reported in these studies, it may be wise for novel trainees to undergo a warm-up period with low-velocity, low-intensity training and gradually progress to exercises with high velocity and moderate intensity. This warm-up period allows older adults to familiarize themselves with the movement patterns and avoid musculoskeletal injuries.

CONCLUSION/RECOMMENDATIONS

The primary purpose of this review article was to analyze the efficacy of high-velocity power training in improving physical function, improving balance performance, and reducing fall incidences in older adults. Exercise interventions targeted at improving muscle power have been well tolerated, safe, and effective for community-dwelling older adults, as well as older adults living with frailty. Specifically, current evidence shows that power training is more successful than strength training in enhancing physical function. Limited evidence also shows that power training can improve balance performance as measured by specific clinical and biomechanical balance measures. However, more research is required to investigate whether power training or strength training is more effective in improving balance performance. No studies have shown that power training effectively reduces fall incidence. This may be because falls are a complex issue that requires a multifaceted approach. However, there is a growing body of evidence to support the use of power training to improve several risk factors for falls, such as muscle strength, functional mobility, and balance. Future large-scale randomized controlled trials are needed to guide the incorporation of power training in fall prevention exercise programs.

As a result of this review, clinical recommendations for power training protocols in older adults include 2 elements, proper duration and intensity. Most of the studies reviewed included a training duration of 3 times per week for 12 to 16 weeks. Therefore, a minimal training duration of 12 weeks may be required for the training to reach its full effect due to the nature of adaptation in the aging musculoskeletal system.[46,47] However, since studies with a wide range of training durations (6-26 weeks) have shown positive outcomes, more studies investigating optimal training duration would be useful. Training beyond 12 weeks may not be practical in a physical therapy setting. On the other hand, training in a community-based program presents the challenge of maintaining proper intensity due to lack of supervision from a physical therapist. Therefore, a fall prevention program implementing power training might ideally be conducted with an interdisciplinary approach including health care professionals and community collaborators.

Comparing high-intensity power training and low-intensity power training, high-intensity power training (80% 1 RM) resulted in a greater increase in muscle power and strength,[32] while low-intensity power training (20%-40% 1 RM) had an equal or greater positive effect on physical function and balance performance.[22,38] This suggests that the velocity component of power training may be a significant factor for improving functional and balance performance since low-intensity power training allows muscle contraction at a higher velocity than high-intensity power training. Because low-intensity training has a relatively lower risk of injury than high-intensity training,[32] power training can be a feasible and well-tolerated intervention for improving physical function and balance performance in older adults with or without frailty.

References

1. World Health Organization. Falls. https://www.who.int/news-room/fact-sheets/detail/falls. Published 2018. Accessed June 18, 2020.
2. Florence CS, Bergen G, Atherly A, Burns E, Stevens J, Drake C. Medical costs of fatal and nonfatal falls in older adults. *J Am Geriatr Soc*. 2018;66(4):693-698. doi:10.1111/jgs.15304.
3. Dionyssiotis Y. Analyzing the problem of falls among older people. *Int J Gen Med*. 2012;5:805-813. doi:10.2147/IJGM.S32651.
4. Gschwind YJ, Kressig RW, Lacroix A, Muehlbauer T, Pfenninger B. Granacher U. A best practice fall prevention exercise program to improve balance, strength/power, and psychosocial health in older adults: study protocol for a randomized controlled trial. *BMC Geriatr*. 2013;13(1):105. doi:10.1186/1471-2318-13-105.
5. Morrison S, Colberg SR, Mariano M, Parson HK, Vinik AI. Balance training reduces falls risk in older individuals with type 2 diabetes. *Diabetes Care*. 2010;33(4):748-750. doi:10.2337/dc09-1699.
6. Cho S-I, An D-H. Effects of a fall prevention exercise program on muscle strength and balance of the old-old elderly. *J Phys Ther Sci*. 2014;26(11):1771-1774. doi:10.1589/jpts.26.1771.
7. Yoshida Y, Marcus RL, Lastayo PC. Intramuscular adipose tissue and central activation in older adults. *Muscle Nerve*. 2012;46(5):813-816. doi:10.1002/mus.23506.
8. Marcus RL, Addison O, Kidde JP, Dibble LE, Lastayo PC. Skeletal muscle fat infiltration: impact of age inactivity and exercise. *J Nutr Health Aging*. 2010;14(5):362-366.
9. Mitchell WK, Williams J, Atherton P, Larvin M, Lund J, Narici M. Sarcopenia, dynapenia, and the impact of advancing age on human skeletal muscle size and strength; a quantitative review. *Front Physiol*. 2012;3:260. doi:10.3389/fphys.2012.00260.
10. Benichou O, Lord SR. Rationale for strengthening muscle to prevent falls and fractures: a review of the evidence. *Calcif Tissue Int*. 2016;98(6):531-545. doi:10.1007/s00223-016-0107-9.
11. Reid KF, Fielding RA. Skeletal muscle power: a critical determinant of physical functioning in older adults. *Exerc Sport Sci Rev*. 2012;40(1):4-12. doi:10.1097/JES.0b013e31823b5f13.
12. Zalewski CK. Aging of the human vestibular system. *Semin Hear*. 2015;36(3):175-196. doi:10.1055/s-0035-1555120.
13. Ekvall Hansson E, Magnusson M. Vestibular asymmetry predicts falls among elderly patients with multi-sensory dizziness. *BMC Geriatr*. 2013;13:77. doi:10.1186/1471-2318-13-77.
14. Saftari LN, Kwon O-S. Ageing vision and falls: a review. *J Physiol Anthropol*. 2018;37(1):11. doi:10.1186/s40101-018-0170-1.
15. Rice J, Keogh J. Power training: can it improve functional performance in older adults? A systematic review. *Int J Exerc Sci*. 2009;2(2):131-151. https://digitalcommons.wku.edu/ijes/vol2/iss2/6. Accessed June 16, 2020.

16. Zech A, Drey M, Freiberger E, et al. Residual effects of muscle strength and muscle power training and detraining on physical function in community-dwelling prefrail older adults: a randomized controlled trial. *BMC Geriatr*. 2012;12(1):68. doi:10.1186/1471-2318-12-68.
17. Miszko TA, Cress ME, Slade JM, Covey CJ, Agrawal SK, Doerr CE. Effect of strength and power training on physical function in community-dwelling older adults. *J Gerontol A Biol Sci Med Sci*. 2003;58(2):171-175. doi:10.1093/gerona/58.2.M171.
18. Katula JA, Rejeski WJ, Marsh AP. Enhancing quality of life in older adults: a comparison of muscular strength and power training. *Health Qual Life Outcomes*. 2008;6(1):45. doi:10.1186/1477-7525-6-45.
19. Drey M, Drey M, Zech A, et al. Effects of strength training versus power training on physical performance in prefrail community-dwelling older adults. *Gerontology*. 2012;58(3):197-204. doi:10.1159/000332207.
20. Bean JF, Kiely DK, LaRose S, Goldstein R, Frontera WR, Leveille SG. Are changes in leg power responsible for clinically meaningful improvements in mobility in older adults? *J Am Geriatr Soc*. 2010;58(12):2363-2368. doi:10.1111/j.1532-5415.2010.03155.x.
21. Bean JF, Herman S, Kiely DK, et al. Increased Velocity Exercise Specific to Task (InVEST) training: a pilot study exploring effects on leg power, balance, and mobility in community-dwelling older women. *J Am Geriatr Soc*. 2004;52(5):799-804. doi:10.1111/j.1532-5415.2004.52222.x.
22. Reid KF, Martin KI, Doros G, et al. 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*. 2015;70(3):374-380. doi:10.1093/gerona/glu156.
23. Sayers SP, Gibson K, Cook CR. Effect of high-speed power training on muscle performance, function, and pain in older adults with knee osteoarthritis: a pilot investigation. *Arthritis Care Res*. 2012;64(1):46-53. doi:10.1002/acr.20675.
24. Henwood TR, Riek S, Taaffe DR. Strength versus muscle power-specific resistance training in community-dwelling older adults. *J Gerontol A Biol Sci Med Sci*. 2008;63(1):83-91. doi:10.1093/gerona/63.1.83.
25. Oliveira BRR, Slama FA, Deslandes AC, Furtado ES, Santos TM. Continuous and high-intensity interval training: which promotes higher pleasure? *PLoS One*. 2013;8(11):e79965. doi:10.1371/journal.pone.0079965.
26. Sayers SP, Guralnik JM, Thombs LA, Fielding RA. Effect of leg muscle contraction velocity on functional performance in older men and women. *J Am Geriatr Soc*. 2005;53(3):467-471. doi:10.1111/j.1532-5415.2005.53166.x.
27. Bean JF, Kiely DK, Herman S, et al. The relationship between leg power and physical performance in mobility-limited older people. *J Am Geriatr Soc*. 2002;50(3):461-467. doi:10.1046/j.1532-5415.2002.50111.x.
28. Cuoco A, Callahan DM, Sayers S, Frontera WR, Bean J, Fielding RA. Impact of muscle power and force on gait speed in disabled older men and women. *J Gerontol A Biol Sci Med Sci*. 2004;59(11):1200-1206. doi:10.1093/gerona/59.11.1200.
29. Suzuki T, Bean JF, Fielding RA. Muscle power of the ankle flexors predicts functional performance in community-dwelling older women. *J Am Geriatr Soc*. 2001;49(9):1161-1167. doi:10.1046/j.1532-5415.2001.49232.x.
30. Bosco C, Komi PV. Influence of aging on the mechanical behavior of leg extensor muscles. *Eur J Appl Physiol*. 1980;45(2-3):209-219. doi:10.1007/BF00421329.
31. De Vito G, Bernardi M, Forte R, Pulejo C, Macaluso A, Figura F. Determinants of maximal instantaneous muscle power in women aged 50-75 years. *Eur J Appl Physiol*. 1998;78(1):59-64. doi:10.1007/s004210050387.
32. Porter MM. Power training for older adults. *Appl Physiol Nutr Metab*. 2006;31(2):87-94. doi:10.1139/h05-034.
33. Sayers SP. High velocity power training in older adults. *Curr Aging Sci*. 2008;1(1):62-67. doi:10.2174/1874609810801010062.
34. Sayers SP. High-speed power training: a novel approach to resistance training in older men and women. A brief review and pilot study. *J Strength Cond Res*. 2007;21(2):518-526. doi:10.1519/R-20546.1.
35. Tschopp M, Sattelmayer MK, Hilfiker R. Is power training or conventional resistance training better for function in elderly persons? A meta-analysis. *Age Ageing*. 2011;40(5):549-556. doi:10.1093/ageing/afr005.
36. Hazell T, Kenno K, Jakobi J. Functional benefit of power training for older adults. *J Aging Phys Act*. 2007;15(3):349-359. doi:10.1123/japa.15.3.349.
37. Bottaro M, Machado SN, Nogueira W, Scales R, Veloso J. Effect of high versus low-velocity resistance training on muscular fitness and functional performance in older men. *Eur J Appl Physiol*. 2007;99(3):257-264. doi:10.1007/s00421-006-0343-1.
38. Orr R, de Vos NJ, Singh NA, Ross DA, Stavrinos TM, Fiatarone-Singh MA. Power training improves balance in healthy older adults. *J Gerontol A Biol Sci Med Sci*. 2006;61(1):78-85. doi:10.1093/gerona/61.1.78.
39. Pamukoff DN, Haakonssen EC, Zaccaria JA, Madigan ML, Miller ME, Marsh AP. The effects of strength and power training on single-step balance recovery in older adults: a preliminary study. *Clin Interv Aging*. 2014;9:697-704. doi:10.2147/CIA.S59310.
40. Horlings CG, van Engelen BG, Allum JH, Bloem BR. A weak balance: the contribution of muscle weakness to postural instability and falls. *Nat Clin Pract Neurol*. 2008;4(9):504-515. doi:10.1038/ncpneuro0886.
41. Moreland JD, Richardson JA, Goldsmith CH, Clase CM. Muscle weakness and falls in older adults: a systematic review and meta-analysis. *J Am Geriatr Soc*. 2004;52(7):1121-1129. doi:10.1111/j.1532-5415.2004.52310.x.
42. Skelton DA, Kennedy J, Rutherford OM. Explosive power and asymmetry in leg muscle function in frequent fallers and non-fallers aged over 65. *Age Ageing*. 2002;31(2):119-125. doi:10.1093/ageing/31.2.119.
43. Gianoudis J, Bailey CA, Ebeling PR, et al. Effects of a targeted multimodal exercise program incorporating high-speed power training on falls and fracture risk factors in older adults: a community-based randomized controlled trial. *J Bone Miner Res*. 2014;29(1):182-191. doi:10.1002/jbmr.2014.
44. Cadore EL, Casas-Herrero A, Zambom-Ferraresi F, et al. Multicomponent exercises including muscle power training enhance muscle mass, power output, and functional outcomes in institutionalized frail nonagenarians. *Age (Dordr)*. 2014;36(2):773-785. doi:10.1007/s11357-013-9586-z.
45. Izquierdo M, Cadore EL. Muscle power training in the institutionalized frail: a new approach to counteracting functional declines and very late-life disability. *Curr Med Res Opin*. 2014;30(7):1385-1390. doi:10.1185/03007995.2014.908175.
46. Walker S, Häkkinen K. Similar increases in strength after short-term resistance training due to different neuromuscular adaptations in young and older men. *J Strength Cond Res*. 2014;28(11):3041-3048. doi:10.1519/JSC.0000000000000381.
47. Borde R, Hortobágyi T, Granacher U. Dose-response relationships of resistance training in healthy old adults: a systematic review and meta-analysis. *Sports Med*. 2015;45(12):1693-1720. doi:10.1007/s40279-015-0385-9.