High Velocity Power Training in Older Adults

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Abstract: Increases in both the age and the number of older adults in the United States will likely result in more people living with functional limitations and physical disabilities. The impact of this change in demographics will not only significantly impact older adult quality of life but may overwhelm existing health care services for this population. Resistance training with a strengthening component is currently recommended for older adults who wish to increase strength and overall health. However, muscle power has recently been found to contribute more to improvement in physical functioning than muscle strength and is becoming a focus of many resistance training studies in older adults. This review will discuss the current research supporting the implementation of traditional strength-enhancing resistance training, examine the contribution of muscle power to function, explore the rationale for implementing high velocity power training interventions, and review the recent literature on these novel power training interventions in older men and women. Recommendations for future research will be discussed.

Keywords: Aging, resistance training, muscle power, contraction velocity, functional ability, exercise adherence and compliance.

INTRODUCTION

The population of the United States is rapidly aging, with approximately 33 million Americans currently 65 years of age or older [1]. In the next 25 years, the population of older adults will rise to nearly 70 million, and the number of men and women 100 years of age or older is expected to increase more than five-fold [1]. Moreover, approximately 20% of older men and women have chronic disabilities [2]. Thus, increases in both the age and the number of older adults in our country will likely result in more people living with, and living longer with, chronic and disabling conditions [3]. This trend in disablement will not only increase the burden on our health care system, but directly affect the quality of life in our older citizens. To maintain independence and quality of life for our aging population, exercise interventions that are successful in preserving functional abilities must be identified and developed.

Despite almost 30 years of resistance training (RT) research with older adults, there is little consensus as to the best strategy to improve function and reduce physical disability in this population. Most experts recommend utilizing a relatively high percentage of maximal force to improve muscle strength [4]. However, increasing muscle strength in this population through strength-enhancing RT has not always equated to improvement in functional ability [5,6]. Although closely related, muscle strength (the ability to produce force) and muscle power (the ability to produce force quickly [5]) appear to differ in their relative contribution to functional task performance, with muscle power demonstrating a greater importance as a predictor of function and disability than muscle strength [6-9]. In the past three decades, hundreds of studies have been performed using strength-enhancing RT in older adults; however, few studies have examined RT using higher velocity movements (power training) in this population. The number of studies employing power training is increasing as the importance of muscle power and its influence on physical functioning and disability has emerged. This review will discuss the research supporting the utilization of strength-enhancing RT in older men and women, examine the contribution of muscle power to functional task performance, explore the rationale for including high velocity power training in this population, and the recent literature on training interventions to improve muscle power. Recommendations for future research and practical direction to advance the field of research will be discussed.

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RESISTANCE TRAINING IN OLDER ADULTS

Resistance training in older adults is essential to counter the age-related declines in muscle mass, strength and power that occurs with aging. After age 50, muscle is lost at a rate of approximately 1-2% per year [10]. Although much of this muscle loss can be attributed to inevitable age-related processes [10-12], reduced physical activity patterns resulting in disuse atrophy are also to blame [11]. Muscle loss and muscle atrophy are important contributor to reductions in strength and power throughout the lifespan. Muscle strength declines about 15% per decade from age 50-70 [13] and there is an even greater loss after the age of 70 [14]. However, meaningful declines in muscle strength are typically not observed much before the age of 50 [15]. On the other hand, muscle power declines sooner and more rapidly than muscle strength, beginning in the third and fourth decade of life [15] and at a rate of 3-4% or greater per year afterward (compared to a 1-2% decline in strength) [16]. The accelerated loss of muscle power compared to muscle strength may be due in part to the loss and atrophy of more powerful type II muscle fibers [17,18], decreases in motor unit recruitment and firing rate [19], increased co-activation and reduced coordination of groups of muscles [19-21], and slowing of nerve conduction velocity [21,22].

Traditional RT with a strengthening component has been shown to improve muscle performance and physiological

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characteristics of the muscle and is widely recommended as part of an exercise regimen for older adults [4]. The traditional approach to RT for older adults has typically emphasized contractions at high external resistances (60-90% of the one repetition maximum [1RM] performed at slow speeds [23-36]). Traditional RT studies in older adult populations regularly demonstrate significant increases in muscle strength [23-36] and hypertrophy of type I, type II (a and b), and whole muscle [23,24,27,30,31,33,35].

Geriatric research has demonstrated a significant relationship between muscle strength and physical functioning [5,8]. Alexander *et al*. [37] reported that older adults may need up to 90% of their knee strength to rise from a chair while younger adults may need only a little more than half that to perform the same task, clearly demonstrating the importance of muscle strength to functional task performance in older adults. However, the impact of RT with a strengthening component on physical functioning is less clear [6,38]. A review by Keysor & Jette [6] and meta-analysis by Latham *et al.* [38] revealed only small improvements in certain functional tasks after traditional RT, despite large and positive effects of this type of training on muscle strength. These data suggest that while strength is necessary for the performance of functional tasks, strengthening the muscle may not necessarily equate to a direct and proportional increase in functional performance. This apparent contradiction may be explained by the non-linear relationship between strength and function [39]. The relationship between strength and function is thought to be curvilinear, creating a threshold (or ceiling) for improvements in function with increases in strength or power [39]. Thus, individuals possessing low levels of strength (who fall on the steeper portion of the curve) would likely demonstrate greater improvement in function by performing RT with a strengthening component compared to stronger individuals (who fall on the flatter portion of the curve) [39]. It may also be that RT with a strengthening component does not transfer positively to functional task performance because of contrasting muscle activation patterns between strength-related movement and function-related movement [19]. For example, typical daily functional tasks may involve more complex muscle activation patterns than the slow velocity, near maximal effort movements encountered during traditional RT [19]. Clearly, some functional tasks may rely on movement speed while others may be more strength related; however, the muscle activation patterns encountered during traditional RT may limit the positive transfer of RT to functional tasks that have more variable speed and force requirements [19].

MUSCLE POWER AND CONTRACTION VELOCITY

In the earliest studies of muscle power in older adults, Bassey and colleagues [40] examined the contribution of muscle power to functional tasks and found that leg extensor power was predictive of stair climb and chair rise performance in a frail older adult population. Other more recent studies have shown that peak muscle power of the leg extensors and ankle plantar flexors are even more predictive of functional task performance than muscle strength [5,7,9]. When tested across a range of external resistances (40%-90% of the 1RM), peak power typically occurs at approximately 70% of the 1RM when tested using lower extremity pneumatic resistance training equipment - see Fig. (**1**). Predictably, contrac-

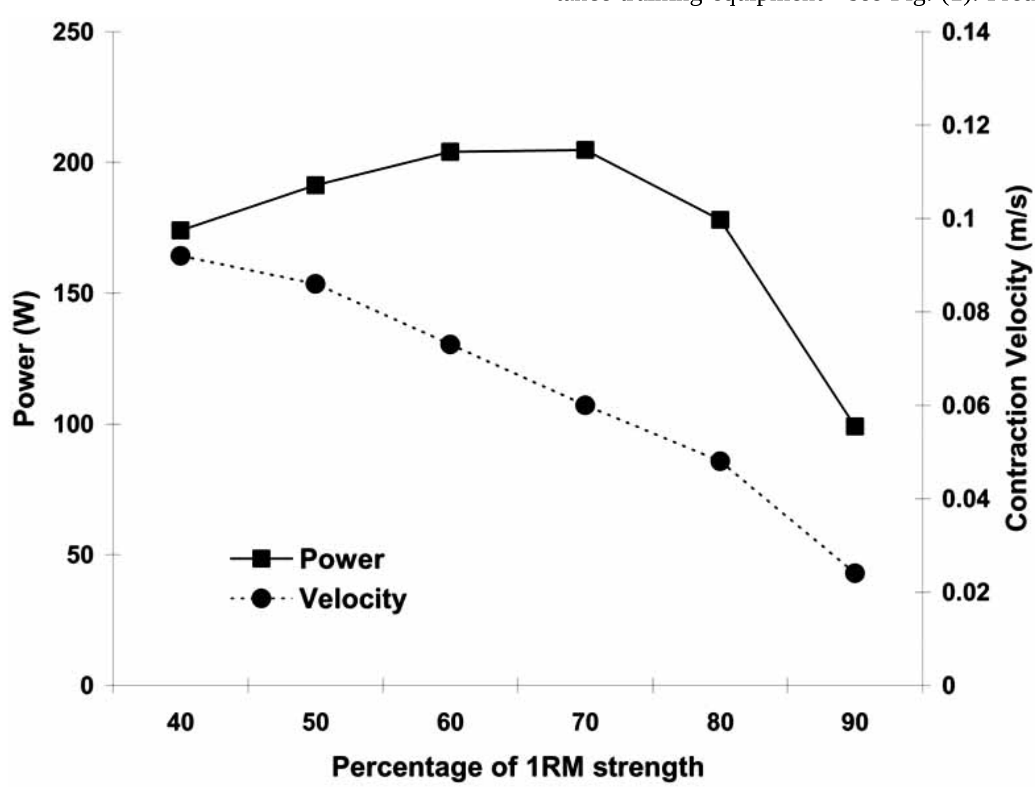

Fig. (1). Muscle power (filled squares) and contraction velocity (filled circles) at various percentages of the one-repetition maximum (1RM). Peak power typically occurs at ~70% of the 1RM, while maximal contraction velocity occurs at the lowest external resistance (40% of the 1RM). Data presented are from a 77-year old male study volunteer.

tion velocity is at its highest at the lowest external resistance. Muscle power developed at higher velocity (40% of the 1RM) appears to explain more of the variability in function than muscle performance variables obtained at slower contraction velocity (peak power) or at the slowest of all contraction velocities (maximal strength) [7]. In addition, the independent effect of the velocity component of muscle power (at 40% of the 1RM) has been shown to demonstrate stronger associations with functional performance in older adults than maximal strength [8]. Because the loss of muscle power with age may be related to comparatively greater declines in velocity than in force [42,43], the critical variable to functional ability may not be how strong the muscles are, but how quickly we are able to move them. In fact, studies have shown that resistance training improved the power producing capability of single muscle fibers in older men, primarily due to increased contractile velocity [44].

Despite the emerging body of knowledge on the benefit of muscle power and contraction velocity, these variables have generally been overlooked when choosing an exercise protocol for older adults. However, muscle power and movement speed are critical to the performance of functional tasks, especially those tasks related to walking. As an example, the typical walking speeds for younger adults range from 1.23 m/s in women to 1.48 m/s in men, respectively [45]. However, Guralnik *et al*. [46] reported that in a cohort of over 5000 older adults, 77% had walking speeds of 0.77 m/s or less. Research has also shown that walking speeds of up to 1.37 m/s may be required to safely cross a typical urban intersection [45]. Because muscle power [5,7] and contraction velocity alone [8] are stronger contributors to walking speed than muscle strength, improving muscle power and speed of movement could be important to the maintenance of walking speed and safe community ambulation. Maintenance of muscle power and movement speed throughout life is also proving to be critical. A recent longitudinal study demonstrated that decreases in high-speed movement time significantly increased the risk of mortality in older men [47].

High Speed Resistance (Power) Training Studies in Older Adults

It is clear from the literature that muscle power and rapid force development can be improved in younger adults employing high velocity RT [48,49]. It is only recently, however, that RT interventions emphasizing movements at higher velocities have been implemented in older adult populations. In these studies, heavy RT regimens involving explosive movements have shown significant increases in strength [50-55], whole muscle cross-sectional area [50,52-55], type I, type II, type IIa and type IIb muscle fiber area, rate of force development and muscle power [50,53-56], neural activation and improved neuromuscular function [50,53-56], and acute increases in serum growth hormone concentration [55]. These mixed-methods RT regimens [57] were also shown to increase the performance of power-related activities similarly between older and younger men [51], likely due to neural adaptations [53,54]. Other studies have compared the effects of peak power training alone versus traditional strength-enhancing RT protocols. Fielding *et al*. [41] reported a 97% improvement in leg press peak muscle power in older women after 16 weeks of power training at 70% of the 1RM, but only a 45% increase after 16 weeks of slow velocity RT at 70% of the 1RM. However, improvements in functional performance and measures of disability were not different in this same cohort despite differences in training velocity [58].

High velocity power training using lower resistances that can accommodate greater speeds of movement has also been examined [59-61]. Earles *et al*. [59] reported improvement in peak muscle power and functional task performance in women training at high velocity compared to women assigned to a walking intervention. However, a limitation to this study was the repeated practice of the functional outcomes measures as part of the training regimen. Thus, the magnitude of the effect of power training alone on function improvement is uncertain. Miszko *et al*. [60] showed that velocity-training at 40% of the 1RM improved measures of whole body functioning compared to traditional RT with a strengthening component. Eight weeks of velocity training at 20%, 50% and 80% of the 1RM improved peak muscle power approximately 14-15% in older adults [61]. It is interesting to note that when compared to traditional RT functional improvement was evident following high velocity power training [60], but not following peak power training [58]. Moreover, high velocity power training at ~20% of the 1RM demonstrated the greatest improvement in balance in a cohort of older adults compared to power training at 50% and 80% of the 1RM [62]. These data suggest that speed of movement during power training may be a critical variable in functional task improvement.

FUTURE DIRECTION

Future studies are warranted to determine the impact of high velocity training regimens in the lives of older men and women. Several unanswered questions relate to the optimal combinations of external resistance and speed of contraction to bring about improvements in muscle performance and function. While several studies have explored this concept [41,60-62], there is little consensus as to the ideal training parameters or whether different training protocols may impart specificity for a particular functional outcome.

Muscle power training must also be evaluated in various patient populations, especially in adults with knee osteoarthritis (OA), the number one medical condition in the United States that contributes to more chronic disability in older adults [63]. A primary focus of research and rehabilitation in older adults suffering from knee OA has been slow-velocity resistance training with a strengthening component. However, high speed contractions appear to improve the metabolic and regenerative processes within the joint of knee OA patients. A study exploring the effect of contraction velocity on intraarticular oxygen partial pressure of the arthritic knee showed that high speed contractions (180°/sec) improved oxygen partial pressure compared to slow speed contractions (60°/sec) [64]. Because increased oxygen partial pressure improves blood flow and diffusion within the joint [64], a mechanism can be proposed to explain why high speed training could improve measures of function, pain, and disability in knee OA patients. We believe that these findings, together with the aforementioned data on the potential functional benefits of muscle power training, warrant the

Table 1. Compliance with Resistance Training during 3 Months of Self-Directed Exercise after 12 Weeks of Laboratory-Based Resistance Training

	Intervention		**p value**
	High velocity RT (40% 1RM; n=6)	**Traditional RT (80% 1RM; n=6)**	
Number of Visits	30.5 ± 2.4	17.3 ± 5.2	0.06
Training Volume (kg)	33,161 ± 15,510	15,869 ±13,155	0.07

exploration of power training interventions using high velocity contractions in knee OA patients.

Another critical area of research that must be examined is the effect of high velocity power training on adherence and compliance with RT exercise regimens. There is a critical need for resistance training protocols that appeal to older men and women and foster long-term participation. Research has shown that only 10% of the older adult population regularly engages in weight training [65]. Cross-sectional research suggests the strenuous nature of exercise is predictive of adherence and compliance, with moderate intensity exercise being a stronger predictor of exercise adherence and compliance than high-intensity exercise [66-68]. Data from our laboratory has shown that perceived exertion during high velocity training (at 40% of the 1RM) appears to be lower than traditional RT (at 80% of the 1RM) [69]. We have also observed a strong trend in our data toward compliance with RT after high velocity training in older men and women (data not published). During 3 months of self-directed exercise at a community facility after a 12-week laboratory-based RT intervention (involving either high velocity or traditional RT), subjects who participated in high velocity training had visited the facility more often and had a greater training volume compared to traditional RT (see Table **1**). We believe that our different resistance training protocols and the perception of the demand of the exercise may be influencing the psychological determinants of exercise behavior. It is well known that psychological constructs such as self-efficacy, task enjoyment, and pain influence participation in exercise behavior [70-72]. Thus, changes in these constructs over the course of a laboratory-based high velocity training protocol may contribute to an increase in compliance with resistance training during self-directed exercise. Future studies should explore the psychological constructs surrounding different exercise regimens to identify the optimal determinants of compliance with RT protocols in older men and women.

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