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HIGH-SPEED POWER TRAINING: A NOVEL APPROACH TO RESISTANCE TRAINING IN OLDER MEN AND WOMEN. A BRIEF REVIEW AND PILOT STUDY

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ABSTRACT. Sayers, S.P. 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. 21(2):518–526. 2007.*—Over the past century, increases in both longevity and the number of older adults in the U.S.A. have given rise to greater numbers of functionally limited and disabled older adults. This has resulted in a decline in the quality of life of our elderly population, as well as an increased burden on our health care system. Resistance training (RT) with a strengthening component has traditionally been recommended to improve health and physical functioning in older adults. Muscle power (force × velocity), or the ability to produce force rapidly, has recently emerged as an important predictor of functioning in older men and women and has been the current focus of many RT studies. In this review, the physiological changes that contribute to the declines in muscle strength and power with aging will first be examined, followed by a discussion of the prevailing theories behind the use of traditional RT in older men and women. The rationale for high-velocity RT will then be explored, and the recent literature on novel training interventions designed to improve muscle power in older adults will be discussed. Finally, some preliminary evidence demonstrating the benefits of high-velocity power training in older men and women will be presented.

KEY WORDS. aging, exercise, muscle power, contraction velocity, physical disability

INTRODUCTION

At the turn of the 20th century, 3 million Americans (4% of the population) were 65 years or older. Today, approximately 33 million Americans are age 65 years or older (13% of the population). This number is expected to double to nearly 70 million (~20% of the population) by the year 2030 and almost triple to 93 million by the year 2050 (21). In addition, adults 85 years or older are the fastest growing segment of the older adult population, and the number of men and women 100 years of age or older is expected to increase more than fivefold by the year 2030 (21). Although older adults in the U.S.A. are increasing in numbers and living longer than ever before, an unfortunate result of this positive trend has been an increase in chronic conditions (38). For example, 1 in 5 older adults over 65 years of age have chronic disabilities (67), and if the average adult reaches the current 77-year life expectancy, it is likely that at least 13 of those years will be lived with some form of physical disability (38). For a country with a growing elderly population, trends in disablement will not only affect quality of life of our aged but will increase the burden on an already overwhelmed health care system. To reduce dependence and improve the quality of life of the older adult population, it is necessary to identify and develop exercise interventions that improve or help maintain measures of function and disability with aging.

Physical activity and exercise has long been promoted to maintain health and reduce functional decline in older adults; however, there is little consensus on the optimal method to achieve these goals. Current recommendations for resistance training (RT) in adults encourage slow-velocity contractions at a relatively high percentage of maximal force (~50–80%) to improve muscle strength (2). Recently, however, muscle power has emerged as an important predictor of functioning and disability in older adults (7, 15, 71, 74). Although strongly associated with muscle strength, muscle power is a distinctly different muscle performance variable. Muscle power is the maximum rate of work performance, or the product of force × velocity. Whereas muscle strength reflects the ability of the muscle to produce force, muscle power reflects the ability to produce force quickly (7). Despite the widespread recommendation of strength-enhancing RT, these protocols have not convincingly demonstrated improvements in measures of function and disability in older adults (43, 48). In addition, despite the influence of muscle power on functional measures in older adults, few studies have examined higher velocity RT interventions designed to improve muscle power in this population.

The purpose of this paper is to examine the research on muscle power and movement velocity in older men and women and discuss the critical importance of these variables to this population. First, the physiological changes that affect the declines in muscle strength and power with aging will be discussed. Next, the prevailing theories behind traditional RT in older men and women will be examined, followed by the rationale for emphasizing higher velocity training in this population. Finally, the recent literature on novel training interventions designed to improve muscle power will be reviewed, and preliminary evidence from the Human Performance Laboratory (HPL) at the University of Missouri–Columbia (MU) demonstrating the benefits of high-velocity power training will be presented.

Age-Related Change in Muscle Mass, Strength, and Power

As we age, physical activity levels decrease, which can result in a downward spiral of reduced muscle mass, compromised physical functioning, and increased physical disability and dependence. Men and women lose approximately 1–2% of their muscle mass per year after the age of 50 (53). This age-associated loss of muscle is known as sarcopenia, a complex etiology involving both age-related conditions as well as changes in human behavior. Age-related hormonal changes contributing to sarcopenia include a decrease in testosterone, growth hormone (GH), and GH-activated insulin-like growth factor (IGF-1), all of which have anabolic roles in stimulating tissue growth (53, 69). Men and women also lose approximately half of the motor units innervating the individual muscle fibers by age 60 because of death of α-motorneurons in the spinal cord (18). Muscle fibers losing neural innervation that are not reinnervated by existing motor units will die and contribute to a loss of muscle fiber number. There is also an age-related increase in inflammatory mediators such as Interleukin (IL)-6, tumor necrosis factor (TNF), and other cytokines, which have been shown to exert a catabolic effect on muscle tissue (69). Behavioral factors that contribute to muscle loss with aging can include disuse atrophy because of reduced levels of physical activity and decreased caloric intake (particularly protein), which compromises growth and maintenance of muscle mass (69).

The loss of muscle mass with aging clearly contributes to the loss of force-producing ability of the muscle because of a decrease in physiological cross-sectional area of whole muscle over time. Metter et al. (55) reported that muscle strength appears to be maintained up to age 50; however, there is an accelerated strength loss thereafter, up to 15% per decade in the sixth and seventh decade (68), with a more precipitous loss after the seventh decade (3). Muscle power, on the other hand, begins to decline in the third and fourth decade of life (55). In addition, the rate of muscle power loss increases after the age of 60 compared with strength loss, with power declining at a rate of 3–4% or greater per year compared with a 1–2% decline in strength per year (65). Because of the differences in the rate of change of strength and power, loss of muscle mass alone cannot be the sole contributor to the comparatively greater loss of muscle power with aging. Muscle power involves both a force and velocity component, thus age-related changes in either the ability of the muscle to produce force or contract at high speed will affect muscle power. With respect to force production, the preferential loss (50) and atrophy (51) of type II muscle fibers with age is an important contributor to loss of muscle power because type II muscle fibers are capable of producing 4 times the power of a type I muscle fiber (20). In addition, there is a decrease in the specific tension (force per cross-sectional area) of single muscle fibers (both type I and type II) with aging (25). Reductions in the intrinsic force-producing capability of muscle tissue with age will compound the decreases in force reductions attributable to muscle atrophy and loss of muscle mass.

Changes in the velocity characteristics of the muscle also contribute to the decrease in muscle power with aging. A slowing of muscle contractile properties can slow the rate of force development. For example, the speed at which actin slides along myosin in older adult muscle is reduced up to 25%, which slows contractile velocity (36, 47). There is also evidence of impaired sarcoplasmic reticulum function and excitation-contraction coupling in humans (45, 46) that could impair the speed of muscle contraction and relaxation (77). Decreases in cortical drive from supraspinal centers and reduced α-motoneuron excitability (from both cerebellum and spinal neurons) can affect motor unit recruitment and firing rate, thus compromising the ability to activate the muscle (5). Changes in the coordination of groups of muscles, such as increases in coactivation of agonist and antagonist muscles, have been reported in older men (44) and women (52). Such increases in coactivation coupled with decreased neural drive to the agonist and decreased coordination among synergist and agonist muscles can reduce net joint torque and slow the rapid development of force (5). A slowing of nerve conduction velocity has also been reported in older adults (64, 78), which could delay peak force development and affect muscle power.

The Traditional Approach to Resistance Training in Older Adults

Only 25 years ago, the first RT studies in older adults to attenuate the loss of muscle mass and strength began to appear in the literature (4, 58). Before these studies, it was thought that older men and women were likely beyond the physiological capacity to demonstrate significant adaptations to RT and that RT might even increase the incidence of injury. However, over the last quarter century, RT has shown many positive results in older adults and is routinely recommended as a part of a healthy exercise regimen. The traditional approach to RT typically emphasizes a relatively high intensity (>65% of the 1-repetition maximum [1RM]) and a slow rate of speed (2–4 seconds for the concentric portion of the contraction) to improve muscle strength. Studies with traditional RT have typically been conducted over a period of 8–16 weeks, with 8–10 repetitions of the RT exercises performed 2–3 times per week. A brief examination of several RT studies completed over the past 15 years clearly demonstrates that traditional RT in older adults of any age (from 50 to 96 years of age), for any duration of exercise (8–84 weeks), using any muscle group in the body (knee extensors, knee flexors, elbow flexors, whole body, lower body) result in significant increases in muscle strength (5–200%) (13, 22, 23, 26, 35, 37, 42, 49, 54, 59, 63, 66, 73, 75) and hypertrophy of type I (13–59%) (35, 49, 66, 73), type II (17–66%) (13, 49, 66), type IIa (34%) (35), type IIb (52%) (35), and whole muscle by computed tomography (8.5–11%) (22) or magnetic resonance imaging (10%) (42).

Undoubtedly, RT with a strengthening component results in improvement in muscle performance characteristics; however, despite the widespread recommendation of traditional RT for adults (2), the effectiveness of this traditional strength training on functional improvement in older men and women is uncertain (43, 48). Keysor and Jette (43) reviewed 31 progressive RT studies published between 1985 and 2000 and reported that most studies examining the effects of traditional RT on strength outcomes (88%) found a large and positive effect. However, only a little more than half of the studies examining the effects of RT on functional measures (61%) showed improvement in these outcomes, and the effects were small to moderate. A meta-analysis by Latham et al. (48) with a large sample size ($n = 3{,}674$) reported that traditional RT also had large and positive effects on muscle strength but only led to small improvements in certain functional tasks, such as walking. Both studies suggested that traditional slow-velocity RT had very little effect on physical disability.

Why Should Resistance Training Improve Function? Understanding the Strength-Function Relationship. It would seem intuitive that muscle strength is an important component of functional task performance, and cross-sectional research has demonstrated significant associations of muscle strength with function in older adults (7, 15). The importance of possessing adequate muscle strength to perform daily functional tasks (e.g., rising

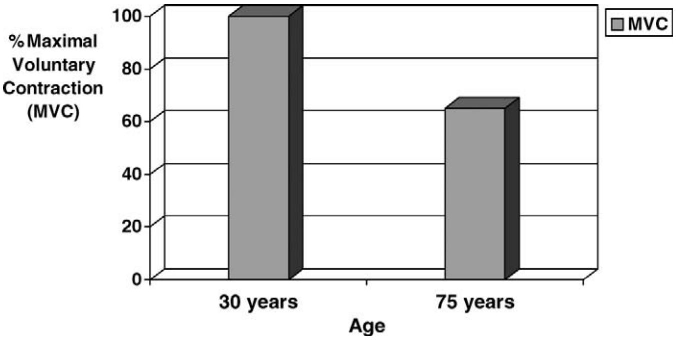

FIGURE 1. Schematic representation of how loss of strength with aging affects functional ability. Patterned area represents the percentage of maximal voluntary contraction required to perform a functional task in young (30 years old) and older (75 years old) adults. In older adults, performing a typical functional task could require a maximal effort. Data modified from Young (79).

from a chair, climbing stairs, etc.) for older adults was superbly described in a model by Young (79) (see Figure 1). This model described how performing a functional task such as rising from a chair could constitute a much lower percentage of maximal strength in a younger person compared with an older adult, who could have lost upward of 30–40% of their strength over their lifetime. Thus, the same task in an older adult might require a maximal effort. In fact, Alexander et al. (1) reported that older adults required up to 87% of their knee strength to rise from a chair, whereas younger adults required only up to 49% to perform the same task. Operating at near maximal strength throughout the course of a typical day could severely compromise the reserve capacity that an older adult has to successfully perform functional tasks without significant fatigue. Thus, older adults possessing greater absolute muscle strength will likely have the capacity to successfully perform the majority of their daily functional tasks because of greater reserve capacity. However, this model cannot account for why increases in strength with RT in older adult populations do not lead to comparable increases in functional performance. To understand this seeming incongruity, it is important to appreciate 2 concepts: the functional threshold and positive transfer of strength to task performance.

The functional threshold states that a threshold level of strength is required to perform a functional task, above which there will be little or no improvement in function with increases in strength (11). The relationship between strength and function is not thought to be linear, but curvilinear (see Figure 2), suggesting that individuals possessing low strength and poor functional ability would benefit most from RT with a strengthening component. Individuals possessing higher levels of strength closer to the threshold strength levels required for performing a particular task (demonstrated by the flat part of the curve, Figure 2) would show little or no improvement in function despite even large increases in strength. Simply put, studies employing highly motivated or very healthy elderly might not observe significant changes in function after RT purely because there is little room for improvement in functioning in these healthy individuals.

It can also be argued that RT with a strengthening component would transfer positively to task performance if muscle activation patterns obtained through training were similar to those required in the particular functional task (5). However, motor tasks performed under typical daily conditions do not usually involve slow velocity, near–maximal effort movements (characteristic of traditional RT). More often, they require movements at higher speeds and variable external resistances. For example, although getting up from a chair and climbing stairs might involve certain basic levels of muscle strength, mobility and balance tasks involved with community ambulation (crossing a busy intersection, negotiating crowded streets or walking in a busy mall) might rely more on higher speed movements. When combinations of physical tasks are incorporated into the spectrum of movement strategies employed by older adults, an atypical pattern of muscle activation (such as traditional RT) might not necessarily demonstrate positive transfer to the functional tasks most frequently encountered during daily activities.

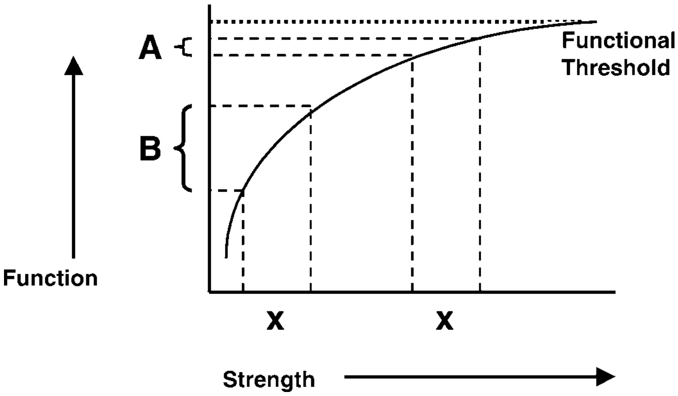

FIGURE 2. Schematic representation of the functional threshold concept, describing the curvilinear relationship between muscle strength and functional task performance. As strength increases, functional performance improves to a point (the functional threshold), above which changes in strength result in very little change in function. Following a resistance training regimen, the functional improvement in a person with moderate to high strength at baseline (a) will be modest compared with a person with low strength at baseline (b), despite identical increases in muscle strength (*x*). Data modified from Buchner et al. (11).

Muscle Power and Function in Older Adults

Muscle power and rate of force development has been evaluated in older adults with the use of a number of different methodologies. These include loaded and unloaded vertical jump performance with or without a force platform (10, 12, 16, 27, 40, 60), isometric and dynamic half-squat (39, 60), loaded bench press (39), rapid isometric and dynamic leg press (28, 29, 31, 33), leg press with the modified leg power rig (6), ankle flexion on an isokinetic machine (74), and leg press and knee extension with computer-interfaced pneumatic RT equipment (7, 15, 41, 71, 74). Bassey and colleagues (6) were some of the first researchers to explore the contribution of muscle power to functional performance in early studies with the leg rig. They showed that leg extensor power in frail older men and women was significantly predictive of stair climb and chair rise functional performance. More recently, studies with pneumatic and isokinetic devices have shown that peak muscle power of the leg extensors (7) and ankle plantar flexors (74) are stronger predictors of functional performance than muscle strength. Because peak muscle power declines sooner and more rapidly than muscle strength (55) and is a more important predictor of functional performance than strength (7, 74), peak muscle power could be a more critical variable on which to focus RT programs in older men and women.

The Potential of High-Velocity Power Training. On the basis of findings from cross-sectional studies reporting the contribution of peak muscle power to functional performance and disability, peak power of the lower extremities could be important to emphasize when training older adults. However, training for muscle power at even greater velocity could be more critical because losses in muscle power with aging appear to be due to greater declines in velocity compared with force (10, 16). Studies are now beginning to focus on the velocity component of muscle power and whether the ability to produce higher speed movements is related to measures of function and disability. Recent studies have shown that muscle power at low external resistance (40% of maximal force, when force is low and contraction velocity is very high) explained more of the variability in functional performance than maximal strength (when force is high and contraction velocity is low) (15). Furthermore, the velocity component of muscle power alone (at low external resistances) has been shown to be a stronger independent predictor of functional performance than maximal strength in older adults (71). In other words, simply how quickly we are able to move the muscles might be more important to functional ability than how strong the muscles are. Improvements in muscle power in single muscle fibers of older men after resistance training were primarily due to the ability to improve contractile velocity (76), suggesting that velocity-based RT protocols could be important to the maintenance and development of muscle power in this population.

How peak muscle power or high-velocity muscle power is important to functioning in older men and women might not be readily apparent, especially when you consider the types of activities in which most older adults participate. When one considers the types of activities that require muscle power, high-intensity athletic endeavors such as ice hockey, football, basketball, or track and field events that require significant force production and maximal speed movements probably come to mind. However, for an older adult, crossing a busy intersection is a power- and velocity-requiring activity. To cross a busy intersection within an allotted time period requires not only force to be produced, but to be produced rapidly. An older adult might be able to produce force in the lower extremities without difficulty, but if the person cannot generate that force quickly, they might not make it across the intersection. In addition, sufficient power is required in the lower limb to move quickly and stabilize the body to prevent a fall if there is a loss of balance. The importance of movement speed and rapid force-producing capability has generally been overlooked when prescribing resistance training exercise for older men and women or those with chronic diseases like knee osteoarthritis. In addition, emphasizing muscle power and contraction velocity over simple muscle strengthening in RT protocols could provide evidence that improvements in function are not purely a byproduct of increased muscle strength but might be more closely associated with speeds of movement typically encountered during daily activities. Moreover, the importance of maintaining muscle power and movement speed is emphasized by a recent longitudinal study that showed a decrease in high-speed movement (tapping) time significantly increased the risk of mortality in older men (56).

Resistance Training Studies Emphasizing Muscle Power in the Elderly. A convincing body of literature concerning younger adults demonstrates that muscle power and rapid force development can be improved with explosive, high-velocity RT vs. heavy-resistance training (30, 62). Only recently, however, have investigators developed RT interventions emphasizing high-velocity movements in older adults. Investigators from Finland (and collaborators in the U.S.A.) were some of the first to identify the importance of muscle power in this population and develop RT regimens to improve muscle power, an attribute not easily trainable in older adults with traditional regimens. In these studies, heavy-resistance training regimens incorporating explosive movements resulted in significant increases in strength (27, 29, 31, 32, 33, 39, 60); rate of force development and muscle power (29, 31, 32, 33, 39, 60); mean muscle fiber area of type I and II (IIa and IIb) and cross-sectional area of whole muscle (27, 29, 31, 32, 39); increased neural activation (and improved neuromuscular function) assessed via electromyography (EMG) (27, 29, 31, 32, 33); and acute increases in serum concentration of anabolic hormones such as GH (33). Several key finds from these studies were that (a) novel mixed-methods RT regimens (61) increased performance of power-related activities similarly between older and younger men (60) and (b) neural adaptations (rapid motor unit activation and firing rate) and not muscle hypertrophy were the likely mechanism by which strength and power improvements occurred in older adults (29, 31). Although these studies did not directly compare explosive versus heavy-resistance training, they established the critical importance of incorporating mixed-methods RT for older adults.

Other studies have sought to compare the effects of power training and traditional RT with a strengthening component. Fielding et al. (24) examined high-velocity power training at a relatively high percentage of the 1RM (70%) and compared this to slow-velocity RT at 70% 1RM. It was reported that leg press peak muscle power in older women was improved (97%) after 16 weeks of RT at higher velocities compared with slow-velocity RT (45%). However, data from the same laboratory examining the effect of power training on functional performance and disability in the same cohort found no advantage compared with traditional slow-velocity RT (70). It could be that these older women were somewhat highly functioning and perhaps possessed baseline strength and power above their functional threshold. Data from a larger study of older men and women using the same power training protocol are currently being analyzed in Dr. Fielding's laboratory to explore how improvements in peak muscle power affect measures of function and disability.

Further studies have examined whether training for increased velocity at lower, perhaps safer, loads can improve key outcomes such as muscle power and measures of function in older adults (17, 19, 57). Earles et al. (19) explored high-velocity training at very low external resistances and found that peak muscle power and several functional tasks were improved compared with a walking intervention. However, the magnitude of the effect of power training alone on function is ambiguous in this study because there was repeated practice of the functional outcome measures during the training period. Miszko et al. (57) reported that velocity-based training at 40% of the 1RM improved measures of whole body functioning compared with traditional strength training. However, the velocity training protocol in this study was preceded by 8 weeks of slow-velocity training at high external resistances, similar to traditional RT programs. Moreover, no measures of muscle power were obtained to determine the effect of velocity training on muscle power output or whether contraction velocity increased. de Vos and colleagues (17) recently showed that velocity training at 20, 50, and 80% 1RM for 8–12 weeks resulted in similar improvements in peak muscle power output (14–15%). However, the effects of these different training regimens on functional outcomes or muscle power across a range of external resistances (commonly encountered during typical daily activities) were not reported in the study. We believe that additional research focusing on muscle power and velocity-based RT interventions in older adults are warranted to determine the most critical contributors to muscle performance and functional improvement in older men and women.

METHODS

Experimental Approach to the Problem

The goal of this pilot investigation was to compare 2 different RT regimens in older men and women. Investigators at MU are currently comparing 12 weeks of high-velocity RT (at 40% 1RM) versus slow-velocity traditional RT (at 80% 1RM) and examining the effects of this training on muscle performance characteristics (muscle strength and peak power, as well as peak power, peak power force, and peak power velocity across a range of external resistances), functional performance measures, self-reported function, and physical disability. All muscle performance characteristics and function and disability measures were obtained at baseline and at 12 weeks in the HPL at MU. We are also exploring how subjects perceive these 2 types of exercise and whether lower perceived levels of exertion might improve adherence to exercise when the laboratory-based intervention is concluded. Although the following data are preliminary in nature, we will discuss some of the trends we have observed thus far in 12 subjects who have completed the protocol. Only muscle performance characteristics (peak power, peak power force, peak power velocity) and perceived exertion are presented in this report.

Subjects

Currently, 12 older adults (3 men, 9 women; age = 74.6 ± 1.9 years; height = 166 ± 1.8 cm; weight = 171 ± 5.6 lbs) have been enrolled and randomized to 1 of 3 groups: velocity-based RT at 40% 1RM (VEL, $n = 5$), slow-velocity RT at 80% 1RM (STR, $n = 4$), or control (CON, $n = 3$). All subjects were apparently healthy and community-dwelling but possessed some limitations in either function or mobility. Exclusion criteria consisted of history of heart disease, osteoarthritis, severe visual impairment, presence of neurological disease, pulmonary disease requiring the use of oxygen, uncontrolled hypertension, hip fracture or knee or hip replacement in the past 6 months, and participation in structured exercise. This research project was approved by the MU Institutional Review Board and written informed consent was obtained from all participants.

Procedures

Maximal Strength and Power Determination. Leg press (LP) and knee extension (KE) 1RM were obtained with Keiser a420 pneumatic (air resistance) equipment (Fresno, CA). The 1RM was obtained by progressively increasing resistance until the subject was no longer able to push out 1 repetition successfully. Ratings of perceived exertion (RPE) according to the Borg scale (9) was also assessed during 1RM testing to assist in evaluating when the 1RM (combined with perceived maximal effort) was successfully reached. All measures were performed twice during the baseline period and once at the end of the 12-week period. Peak muscle power was obtained at 40, 50, 60, 70, 80, and 90% of the 1RM. Subjects were instructed to exert "as fast as possible" at each of these relative percentages of the 1RM. Three attempts were made at each resistance and the best peak power (PP) measure at each resistance was used in the analysis. From these power curves, the force exerted at peak power (PPF) and the velocity achieved at peak power (PPV) were obtained. The 1RM measures and power measures were obtained and adjusted every 2 weeks to ensure adequate overload during the training period. The theory behind pneumatic resistance training is described briefly as follows: during each concentric muscle action in which the movement arm is moved through its range of motion, a piston is driven into a cylinder, where it encounters the mechanical resistance of the air pressure in the system. The computer-interfaced a420 equipment is designed to capture measures of work, velocity, power, and acceleration during the concentric portion of each contraction by sampling the system pressure 400 times per second and making calculations with the use of an appropriate algorithm.

Training Protocol. Subjects in VEL and STR were trained 3 times a week for 12 weeks on the Keiser a420 pneumatic LP and KE equipment. The VEL group performed 3 sets of 12–14 repetitions as fast as possible during the concentric phase, paused for 1 second, then performed the eccentric phase of the contraction over 2 seconds. The STR group performed 3 sets of 8–10 slow-velocity repetitions over 2 seconds during the concentric phase, paused for 1 second, then performed the eccentric phase of the contraction over 2 seconds. We chose the number of repetitions for each group on the basis of what we believed were realistic and practical training regimens given the percentage of 1RM training, as well as recommendations by the American College of Sports Medicine (2). Although work output was likely lower in VEL (data not yet analyzed), studies have shown that improvements in physical functioning have occurred with less total work performed (57), so matching total work was not the primary concern. The CON group performed no RT during the 12 weeks but participated 3 times a week in the same warm-up and stretching exercises that VEL and STR were provided before each training session. During all training sessions, RPE was obtained after each set of exercises. Three values were obtained each training session (for both LP and KE), and the average of the RPE scores over the 36 sessions in the 12-week training program were used in the analysis.

Statistical Analyses

Descriptive statistics were run on all variables. Reliability and consistency of baseline muscle strength and power tests were evaluated with intraclass correlations (R) and analysis of variance (ANOVA), respectively. Statistical significance for ANOVA models was accepted at $p \leq 0.05$. Data are reported as mean ± *SEM*, or percent change from baseline.

RESULTS

For brevity, only data from the KE exercise is presented. Reliability for muscle performance tests was $R = 0.98$

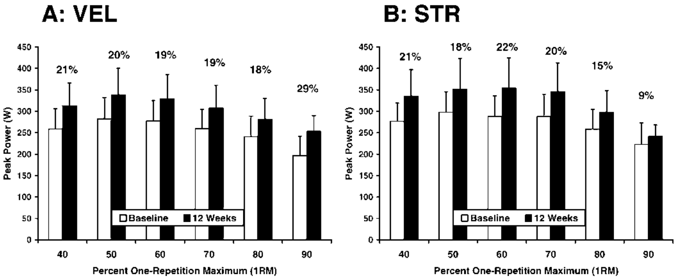

FIGURE 3. Knee extension peak power at external resistances ranging from 40 to 90% of the 1-repetition maximum (1RM) after 12 weeks of resistance training for (a) velocity training (VEL) and (b) strength training (STR). All data represent mean ± *SEM*.

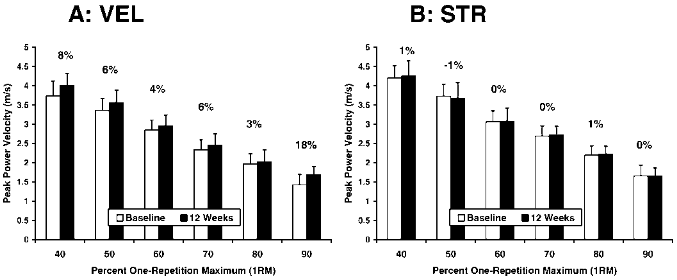

FIGURE 5. Knee extension peak power velocity at external resistances ranging from 40 to 90% of the 1-repetition maximum (1RM) after 12 weeks of resistance training for (a) velocity training (VEL) and (b) strength training (STR). All data represent mean ± *SEM*.

(ANOVA; $F = 3.5$, $p = 0.07$) for KE strength, $R = 0.99$ (ANOVA; $F = 1.03$, $p = 0.33$) for KE PP, $R = 0.97$ (ANOVA; $F = 0.80$, $p = 0.39$) for KE PPF, and $R = 0.91$ (ANOVA; $F = 0.37$, $p = 0.56$) for KE PPV, suggesting that our measures were consistent and reliable. Because our CON group demonstrated no observable changes in any outcome measures, as expected, the following data are presented for the VEL and STR groups only.

Baseline KE strength was 731 ± 84 N for VEL and 686 ± 64 N for STR. The VEL group showed a modest improvement in 1RM strength from the baseline value (14%) compared with STR (21%). Figure 3a,b shows that velocity training improved PP from the baseline value (19–28%) across a range of external resistances (from 40 to 90% 1RM), as it did with STR (9–22%). The force exerted at peak power improved 11–14% from the baseline value across a range of external resistances in VEL (Figure 4a) and improved 16–24% in STR (Figure 4b). The velocity achieved at peak power improved 3–18% from the baseline value across a range of external resistances in VEL (Figure 5a) but showed very little change (–1 to 1%) in STR (Figure 5b). The VEL group demonstrated an aggregate RPE score of 12.6 over the 36 training visits; STR, however, reported an aggregate RPE score of 15.4 over the 36 training visits.

DISCUSSION

We believe it is important to identify the individual characteristics of both velocity and force and their effect on muscle performance and function in the research setting. While acknowledging the preliminary nature of our initial findings, the following data suggest that velocity-based training could have important implications for older men and women. Differences in strength improvement after training (VEL 14%; STR 21%) were expected given the different relative training stimuli. It was interesting to note that increases in peak muscle power with velocity training appeared to be better maintained at high external resistances (80–90%) compared with traditional strength training. In addition, the manner in which each group improved peak muscle power differed on the basis of their training regimen. The STR group appeared to improve PP predominantly through an increase in PPF (see Figure 4b), but not with increases in PPV (see Figure 5b). The VEL group appeared to improve PP through a modest increase in both PPF (see Figure 4a) and PPV (see Figure 5a). Because power is related to both force and velocity, these data suggest that training for velocity, even at low external resistances, could be a key to improving muscle power.

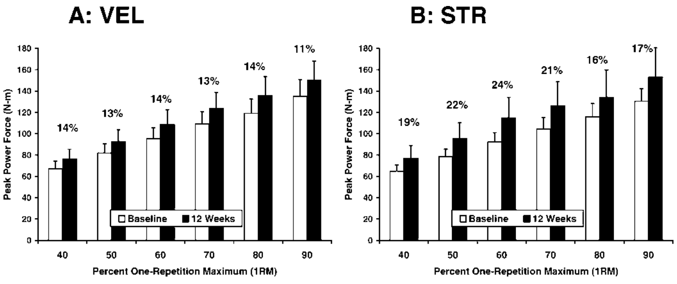

FIGURE 4. Knee extension peak power force at external resistances ranging from 40 to 90% of the 1-repetition maximum (1RM) after 12 weeks of resistance training for (a) velocity training (VEL) and (b) strength training (STR). All data represent mean ± *SEM*.

It will be of considerable interest in our study to determine whether speed of movement and the muscle activation patterns developed during velocity training will transfer to functional activities. A cursory examination of functional changes with high-velocity and traditional strength training has so far revealed small trends in improvement in several of our functional tasks (data not shown), but there have been no observable differences between the different training regimens. The same trends in improvement have been observed with measures of physical disability. Although velocity training has not yet shown clear improvements in measures of function and disability compared with traditional strength training, training at lower external resistances (and higher speeds) resulted in less perceived exertion during KE exercises (see Figure 6). The aggregate score of 12.6 with velocity training corresponded to a perceived exertion between "light" and "somewhat hard," whereas the RPE score of 15.4 with traditional strength training corresponded to perceived exertion between "hard" and "very hard."

Although research on adherence to RT exercise is limited, studies suggest that low- to moderate-intensity endurance exercise improves adherence compared with high-intensity exercise (14, 34). These findings could be of particular importance because only 10% of the older adult population currently participates in resistance exercise (72), perhaps because of the vigorous nature of most RT protocols. Although it is not known yet whether velocity training alone has a more beneficial effect on muscle power and measures of function or disability compared with traditional RT, even if there is no difference in these outcomes but the exercise is perceived as more tolerable, adherence to RT exercise in our older adult populations could be improved. To test this theory, our re-

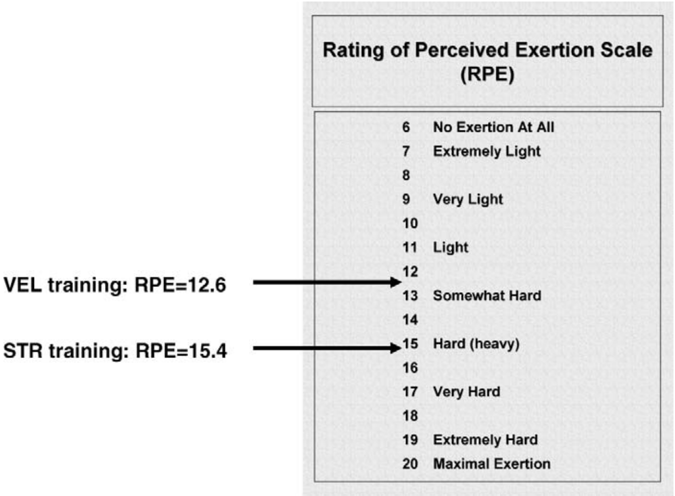

FIGURE 6. Ratings of perceived exertion (RPE) during 12 weeks of resistance training in velocity training group (VEL) and strength training group (STR). Data represent the average RPE of all 36 training sessions.

search group will be evaluating adherence and compliance to self-directed exercise behavior for 3 months of follow-up in this cohort.

Power training with the use of exercise machines such as those used in this study does present some limitations, however. Because exercise machines incorporate a fixed movement pathway, there is little activation of synergist muscles that contribute to strategies involved in functional performance. Although we have not observed any detrimental effects of machine training on functional performance, a study by Bellew et al. (8) reported that machine training in older men might have worsened balance evaluated by postural sway.

PRACTICAL APPLICATIONS

The need today is to identify exercise interventions that improve performance of functional tasks and reduce physical disability in our older adults to help improve their quality of life and maintain their independence. For the health professionals and trainers working with older adults, the incorporation of higher speed power training sessions within an exercise program are recommended. It is important to clarify that an optimal training method to integrate the various aspects of the neuromuscular system likely involves periodization of both high-velocity and heavy-resistance training because no 1 element of muscle power can truly be targeted in isolation. This periodized approach would also improve the quality of training by permitting adequate rest periods from more strenuous exercise sessions. Unless investigators definitively determine a distinct advantage to velocity training compared with traditional RT (e.g., significant improvements in measures of function and disability or improved adherence to exercise), complementing traditional RT with velocity training might be the most prudent application of this novel training regimen.

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