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A review of the effects of different resistance training prescriptions on cognitive function in older adults

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Abstracts

BACKGROUND: The effects of resistance training on brain structure and cognitive function in older adults have now received widespread attention, but the effectiveness of the intervention and the related mechanisms of influence require an exercise prescription dose relationship perspective in order to make a comprehensive judgement on its benefits and many controversies.
METHODS: A literature review was used to explore the effects of different resistance training methods on the brain and cognitive function of older adults, with the help of PubMed, Springer and Web of Science (Core Collection) databases to collect and collate resistance training related

literature, search keywords include: resistance training prescription; cognitive function; prescription dosage; functional resistance training; older adults.
RESULTS: High total training volume and medium to high intensity resistance training may be more effective in enhancing executive function; different resistance training modes, especially unstable plane resistance training and high-speed resistance training, are effective in enhancing cognitive function in middle-aged and elderly populations; complex and challenging resistance training or cognitive work-intervention resistance training are more positive for cognitive improvement in older adults.
CONCLUSION: Training at least twice a week, as well as complex, challenging training with traditional or modified modalities, may contribute to cognitive function; there is no consensus on the optimal total amount of resistance training, rest periods, and training modalities for different populations, and further in-depth discussion is needed in the future.

Keywords: resistance training prescription; cognitive function; prescription dosage; functional resistance training; older adults

Preface

With the global trend of aging, cognitive decline in the elderly population is surfacing as an important factor affecting the health and quality of life of older adults [1]. Cognitive decline will have a negative impact on older adults' self-care ability, social participation, and disease resistance [2]. Therefore, the maintenance and enhancement of cognitive function has become an important issue in elderly health [3].

Resistance training, also known as strength training or resistance training, is a type of traditional muscular fitness training, which aims to improve muscle strength, muscle endurance, and muscle volume by countering a certain degree of resistance so that the muscles are sufficiently challenged and stimulated [4,5]. In recent years, research on the effects of resistance training on cognitive function has been increasing, and it has been found that resistance training can improve cognitive performance, brain volume, and related neurophysiological indices in healthy or cognitively impaired middle-aged and older adults, and that older adults who regularly engage in resistance training have higher performance in cognitive domains such as memory, attention, and decision-making ability [4,6,7]. Therefore, resistance training may be an alternative type of exercise to promote or maintain cognitive function. Although resistance training enhances cognitive function, differences in prescription parameters such as training intensity, training frequency, and type and duration of training may significantly affect the training effect in real-world applications [8].

In the examination of the cognitive effects of resistance training prescriptions, a reliable theoretical framework is provided by Tomporowski and Pesce's [9] model, which divides the influencing factors into two dimensions: prescription dosage - a "quantitative" factor dominated by frequency, intensity, number of sets, and volume of training - and movement patterns - a "qualitative" factor dominated by subjective The model divides the influencing factors into two dimensions: prescription dose - the "quantitative" factor based on frequency, intensity, number of sets, and volume of training, and movement patterns - the "qualitative" factor based on subjective performance. Within the discussion of quantitative factors, an overview of the literature exists suggesting that resistance training three times per week may be more effective than two times per week in middle-aged and older populations [10].

However, this overview does not include the literature on frequency of performance and only compares different studies on three times per week and twice per week training, without considering other differences in prescribed doses. At the same time, there are inconsistent findings regarding the effects of variables such as intensity, volume per unit of training, and frequency on cognitive function. With regard to the examination of "qualitative" factors, the movement patterns of resistance training are heterogeneous depending on the goal.

Most of the available studies have used traditional resistance training with the primary goal of muscle strength, especially muscle hypertrophy, as an intervention program [11]. However, recent findings suggest that unstable plane resistance training [12], high velocity resistance training [13], and functional resistance training [14] may also be beneficial for cognitive function. Therefore, more research is needed to investigate how to select and configure appropriate resistance training prescriptions for older adults to maximize cognitive gains.

In summary, the aims of this paper are (i) to review and collate existing studies to explore and clarify how to improve cognitive function in older adults through resistance training prescription. (ii) Help clinical staff, rehabilitation trainers and other related staff to develop scientific training programs for cognitive health in older adults to achieve healthy ageing. (iii) To provide suggestions and references for future research directions.

1 Research methodology

1.1 Literature Search Strategies

An online search was conducted using PubMed, Springer and Web of Science (Core Collection) databases for the following search terms: Resistance Training, Training Prescription, Cognitive Function, Elderly, Training Frequency, Training Volume, Training Intensity, Unstable Plane Resistance Training, High-Speed Resistance Training, Functional Resistance Training, and Resistance Training, Training Prescription, and Cognitive Function Indicators were used as the main screening basis.

1.2 Literature screening criteria

This paper focuses on the criticality of resistance training strategies and the literature put into consideration is centered around the comparison of multiple resistance training modalities. The basic guidelines for literature inclusion: The intervention duration of the study needs to be greater than one month, so that changes in neurological and muscular adaptations after resistance training can be clearly observed, and the study must design two or more resistance training strategies in order to compare the effects of different training modalities. Second, through the free weights, resistance band fitness equipment, their own body weight and other design of training programs, but the development of training programs must be in line with the "American College of Sports Medicine (ACSM)" guidelines: a minimum of 2-3 times a week, sustained There is no limit to the intensity of load lifting. Measurement data should include: any measure of executive function, cognitive function, cognitive disease, and memory.

1.3 Literature screening results

In this study, a total of 849 articles of related literature were obtained from the search, 343 articles were excluded by reading the titles and abstracts, and the full text was further read according to the literature screening criteria, focusing on the issues of intervention design, training prescription, and indicators of cognitive function test, and 490 articles of irrelevant literature were excluded again, and finally 16 experimental articles were obtained for the study.

2 The effect of prescribed doses of resistance training on cognitive functioning

2.1 Training frequency

Steib et al [15] noted that the training variable of resistance training frequency has been largely underappreciated. Resistance training frequency is influenced by other training variables as well as the physical adaptations of the individual when faced with the mechanical stresses placed on the body [16].Kraemer and Ratamess [17] defined resistance training frequency as the number of training phases performed in a given period of time. When designing a training program, it is important to consider inter-training recovery, as applying resistance training stimuli too frequently to the same muscle or the same muscle group can lead to overtraining and strength loss [18]. Correspondingly, excessively long inter-training recovery may negatively affect muscle strength due to insufficient exercise [19]. Similarly, cognitive function in older adults likewise receives an effect of resistance training frequency.

In the study by Fallah et al [20], the effect of training frequency on cognitive performance was examined from a unique perspective.155 healthy older women (mean age 69 years) participated in a one-year intervention. The study set up a resistance training group that included small deep squats, small split-leg squats, lunge walks, bicep curls, triceps extensions, seated rowing, latissimus dorsi pulldowns, leg push-ups, leg curls, and calf raises. The intensity of each movement was set at 7RM for 6-8 pulldowns. Two sets of each movement were performed and the frequency of training was one or two times per week. The rest period between each set was 60 seconds. Specifically, participants' selective attention and inhibitory control could be significantly improved by enhancing training frequency. This provides the basis for empirical research on the effects of training frequency on improving cognitive function. Liu-Ambrose et al [21] set up a one-year intervention study with 155 healthy older women (mean age 69 years). The study used resistance training as an intervention and covered a number of movements such as small deep squats, small split-leg squats, lunge walks, biceps curls, triceps extensions, seated rowing, latissimus dorsi pull-downs, leg push-ups, leg curls and calf raises. The intensity of each movement was set at 7RM for performing 6-8 pulldowns depending on the individual's ability. two sets of each movement were performed, and the frequency of training was either once or twice a week, with a rest period of 60 seconds between sets. The study found that following resistance training, inhibitory control and selective attention improved, whole brain volume degradation was reduced, and both muscle strength and gait improved. In addition, it was found that the group that trained twice a week showed more significant improvements in inhibitory control and frontal cortex activity compared to the group that trained once a week and the control group. The study by Best et al [22], on the other hand, focused on the effect of training frequency on inhibitory control and other cognitive and physiological indicators. The one-year intervention study included 155 healthy older women (mean age 69 years).

In that study, resistance training was used as an intervention covering several movements including small deep squats, small split-legged squats, lunge walks, biceps curls, triceps extensions, seated rowing, latissimus dorsi pull-downs, leg push-ups, leg curls, and calf raises. The intensity of each movement was set at 7RM for performing 6-8 pulldowns depending on individual ability. Two sets of each movement were performed and the frequency of training was once or twice a week with 60 seconds of rest between sets.

The results of the study showed that once-weekly inhibitory control training was superior to twice-weekly training and the control group in terms of improvement. However, twice-weekly and once-weekly training performed comparably in terms of the protective effect of inhibitory control, both being stronger than the control group. In addition, twice-weekly training showed more significant effects in protecting verbal memory, brain white matter volume, hippocampal gyrus volume, and muscle strength compared to once-weekly training and the control group. Bolandzadeh et al [23], on the other hand, conducted a one-year intervention study recruited 155 healthy, elderly females (mean age 69 years). The study used resistance training as an intervention covering a number of movements such as small deep squats, small split-legged squats, lunge walks, biceps curls, triceps extensions, seated rows, latissimus dorsi pull-downs, leg push-ups, leg curls and calf raises. The intensity of each movement was set at 7RM for 6-8 pulldowns depending on the individual's ability. two sets of each movement were performed, and the frequency of training was either once or twice a week, with a 60-second rest period between sets. In contrast, studies have shown that the effects of training frequency on brain volume changes and gait show correlations rather than significant effects on executive function. Different training frequencies may produce different results, which is especially critical when developing individualized training programs for different age groups and conditions.

From the above studies, it is clear that training frequency has a significant effect on cognitive performance and physiological indicators. In particular, higher training frequency significantly improved selective attention and inhibitory control, as well as contributing to a slowing of whole-brain volume degeneration and improvements in muscle strength and gait. In addition, both once-weekly and twice-weekly training were superior to controls in inhibitory control, but twice-weekly training showed more significant effects in terms of preserving verbal memory, brain white matter volume, and hippocampal gyrus volume. These findings imply that training frequency plays a key role in the effects of cognitive and physiological functioning, and therefore individualized training programs need to be developed for different populations and goals.

2.2 Training intensity

Several parameters (e.g., training frequency, training volume, training and intervention duration, and rest periods between rounds and training sessions) play a key role in resistance training methods and strategies. However, the element of "intensity" is particularly important among these parameters. From a physical point of view, intensity can be measured by the rate of positive mechanical power generated during exercise. From a physiological perspective, resistance training intensity is understood to be the load or weight used in training [24]. RT intensity can be evaluated subjectively through the perception of exertion as well as mental and muscular fatigue [25,26].

Typically, this intensity is calculated based on a percentage of an individual's one repetition maximum (1RM). High-intensity resistance training usually refers specifically to training based on more than 70% of one repetition maximum (1RM) [27]. However, it has been suggested that the intensity of resistance training should take into account factors such as rest between sets and total training volume. Training with low weights combined with short rests may be more fatiguing than training with high weights combined with long rests [28].

Therefore, this paper considers factors such as load, number of repetitions, rest between sets, and training volume in the literature search for the keyword "training intensity" rather than focusing solely on the concept of intensity, in order to more accurately understand the true extent of the cognitive impact of these factors.

In a study by Cassilhas et al [29], 62 healthy older adults between the ages of 65 and 75 years participated in a 24-week resistance training program. The training program included chest presses, leg presses, vertical drags, curling exercises, leg flexor machine training, and lower back training. The training intensity was set at 80% or 50% based on one repetition maximum (1RM). Two sets of each exercise were performed and the training frequency was set to three times per week. There was a 90-second rest period between each set of training and a 180-second rest period between each apparatus. The results of the study showed that this resistance training procedure had positive effects in enhancing functional executive, numerical short-term memory, visual short-term memory, and long-term contextual memory. Also, the training led to an increase in IGF-1 (insulin-like growth factor-1) in the participants. In addition, regarding the effects on attention, training with a moderate intensity load was significantly better than the control group. The study by Marston et al [30] conducted a 12-week training study on 45 healthy middle-aged and older adults between the ages of 41 and 69 years. The training program consisted of four movements: barbell bench press, leg press, pulley pull down and leg curl machine. Training intensity was developed based on one repetition maximum (1RM), and the researchers assigned participants to two intensity regimens: 85% of 1RM for five repetitions, or 70% of 1RM for 10 repetitions. In addition, each movement needed to be performed for either five or three sets. In terms of training frequency, the researchers scheduled two workouts per week with either 180-second or 60-second rest periods between sets. Upon completion of the 12-week training period, the study found that participants showed significant improvements in delayed verbal memory and muscle strength.

From the above studies, it is clear that any resistance training that maintains a gradual increase in intensity from moderate to high loads may positively affect cognitive function (mainly memory) and physical fitness in middle-aged and older adults. However, whether moderate versus high intensity training affects all types of executive functions and memory is something that future research will have to further explore.

2.3 Training volume

Resistance training volume is the total amount of work done when performing resistance training and is usually measured in terms of weight (e.g., kilograms) and number of repetitions (e.g., reps/set) [31]. Specifically, it is the sum of the weight times the number of repetitions times the number of sets for each training exercise. Resistance training volume = number of repetitions × number of sets × intensity load (in kg) or simply calculated as the number of sets per muscle group per week [32,33]. Although different variables in resistance training elicit different intracellular signaling responses and thus morphological adaptations [34], resistance training volume may play an important role in muscle adaptation [35]. In addition, it has been found that voluntary rounds of running increased mRNA levels of nerve growth factor only 6 hours after running, thus suggesting that brain-derived neurotrophic factor mRNA levels are related to volume rather than exercise intensity [36].

Fortes et al [37] explored various effects of differences in the volume of resistance training on a young population (age 18-30 years). The study lasted 40 weeks and 27 subjects were selected for resistance training. The training consisted of four movements: barbell bench press, leg press, seated row, and leg curl machine, with one set of each four movements, and the intensity of each set was set to 10 repetitions of 10RM per movement, and the participants were randomly assigned to complete one set (9), three sets (9), and five sets (9), and the frequency of the training was three times per week. The results of the study revealed the volume of resistance training and the corresponding effects in terms of inhibitory control, reaction time, muscle strength, and fat-free body weight. With respect to inhibitory control and reaction time, five sets of training and three sets of training were significantly more effective than one set of training. In terms of muscle strength, five-set training was the most effective, followed by three-set training, and one-set training was the least effective. And in terms of fat-removing body weight, five-set training was significantly more effective than one-set training. Immediately following Fortes et al [38] explored the effects of varying the frequency of resistance training and the number of sets completed on executive function while the total amount of resistance training was held constant. Thirty-six trained young adults (aged 18-30 years) were randomly assigned to six sets once a week (12), three sets twice a week (12), and two sets three times a week (12) for a 24-week period of resistance training. The training movements consisted of four movements: barbell bench press, leg press machine, seated rowing, and leg flexion machine, with the intensity of each movement set at 10 RM for 10 repetitions, and the completion of four movements as a group, with specific rest periods between groups not given. After 24 weeks of intervention, the results showed no significant difference between the groups.

In summary, in the older group, twice-weekly training frequency was more effective than once-weekly (or higher training totals were more effective than lower ones). However, in the younger group, the effect of total weekly training volume on inhibitory control may have been more pronounced compared to the effects caused by training frequency and single training session volume. Although the groups involved may have made some difference to the results of the experiments [39], it was still found that for both groups, the effect of total weekly training volume on executive functioning, particularly inhibitory control, may be more beneficial than that of a lower training volume.

It has been shown that exercise dose may show a non-linear dose-response relationship on cognition in middle-aged and older adults [40], and that the optimal training volume is slightly higher than the minimum training volume recommended by the ACSM. Thus, the effects of resistance training on cognition in middle-aged and older adults may exhibit a dose-response pattern - benefits increase with increasing exercise volume, but the enhancement slows down after reaching a plateau until it declines. In contrast, a trend towards cognitive improvement with total training volume has been shown in younger age groups. And whether a dose-response curve and plateauing period similar to that in older age groups will occur remains to be further studied and confirmed.

Table 1: Statistics of studies on the effect of prescribed dose of resistance training on cognitive functioning

Author/ Year	**Subject of intervention**	**Duration of intervention**	**Training programs**	**Main results**
Marston et al. (2019)	45 healthy middle-aged and older people (average age 55)	12 weeks	**Movements:** Including barbell bench press, leg press, pulley pull down, leg curl machine **Intensity:** Choose 85 percent of 1RM for five reps; or 70 percent of 1RM for 10 reps **Sets:** Perform five or three sets of each movement Frequency: Twice a week **Rest:** Choose 180 seconds or 60 seconds to rest	1、Verbal memory skills have been improved 2、Muscle strength has also increased significantly
Liu-Ambrose et al. (2010)	155 healthy elderly women (average age 69)	A year	**Movement:** Includes small deep squats, small split squats, lunge walks, biceps curls, triceps extensions, seated rows, latissimus dorsi pull downs, leg presses, leg curls and calf raises **Intensity:** 6-8 reps of each movement usings even repetitions of maximum strength (7RM) **Sets:** Complete two sets of each movement	1、Inhibitory control is improved 2、Increased selective attention 3、Reduced degradation of whole brain volume 4、Significant increase in muscle strength 5、Improved gait

			Frequency: One or two sessions per week **Rest:** 60 seconds between sets	6、 Changes in inhibitory control and frontal cortex activity: twice-weekly training was better than once-weekly training, and better than controls
Cassilhas et al. (2007)	62 healthy older people (average age 70)	24 weeks	**Movements:** Including chest press, leg press, vertical pull down machine, curls, leg curl machine, lower back training **Intensity:** Choose a weight that is 80% of 1RM or 50% of 1RM **Sets:** 2 sets of each movement **Frequency:** 3 sessions per week **Rest:** 90 seconds between sets, 180 seconds when changing machines	1、Executive functions have been upgraded 2、Improved short-term memory for numbers 3、Visual short-term memory is enhanced 4、Enhanced long-term contextual memory 5、Increased IGF-1 concentration 6、Attention was improved in the medium load group compared to the control group
Fallah et al. (2013)	155 healthy elderly women (average age 69)	A year	**Movements:** Includes small deep squats, small split-legged squats, lunge walks, bicep curls, triceps extensions, seated rows, latissimus dorsi pull-downs, leg push-ups, leg curls, and calf raises	1、 Selective attention has improved 2、 Increased inhibitory control

			Intensity: 6-8 repetitions of each movement using seven repetitions of maximum strength (7RM) **Sets:** Complete two sets of each movement **Frequency:** One or two sessions per week **Rest:** 60 seconds between sets	
Fortes et al. (2018)	36 young people with training experience (average age 24)	24 weeks	**Movements:** Including barbell bench press, leg press, seated row, leg curl machine **Intensity:** 10 reps of each movement with a 10RM weight Number of sets:6,3 or2 sets of each movement respectively **Frequency:** 1, 2 or 3sessions per week **Rest :** unspecified	1、No significant difference between groups
Best et al (2015)	83 healthy older women (mean age 89)	A year	**Movements:** Includes small deep squats, small split-legged squats, lunge walks, bicep curls, triceps extensions, seated rows, latissimus dorsi pull-downs, leg push-ups, leg curls, and calf raises **Intensity:** 6-8 repetitions of each movement using seven repetitions of maximum strength (7RM) Sets: Complete two sets of each movement **Frequency:** One or two sessions per week	1、Improvement in inhibitory control after receiving the intervention :once a week was better than twice a week, both better than the control group 2、Protective effect of inhibitory control: twice a week was equal to once a week, both better than control 3、Protective effects on verbal

			Rest: 60 seconds between sets	memory, cerebral white matter volume, hippocampal gyrus volume and muscle strength: twice a week was better than once a week, all better than the control group
Fortes et al (2018)	27 healthy young people (average age 24)	40 weeks	**Movements:** Including barbell bench press, leg press, seated row, leg curl machine **Intensity:** 10 reps of each movement with a 10RM weight **Number of sets:** One set for each movement **Frequency:** Monday, Wednesday and Friday of every week. **Rest:** Unspecified	1、Suppression control: both groups 5 and 3 were better than group 1 2、Reaction time: both group 5 and group 3 had faster reaction times than group 1 3、Muscle strength:5sets were the most effective, followed by 3 sets, and 1 set was the least effective 4、Fat-removal weight: 5 sets lost the most fat weight, 1 set was second best
Bolandzadeh et al (2015)	52 healthy older women (mean age 89 years)	A year	**Movements:** Includes small deep squats, small split-legged squats, lunge walks, bicep curls,	1、Elsewhere, improvements in brain volume showed a

			triceps extensions, seated rows, latissimus dorsi pull-downs, leg push-ups, leg curls, and calf raises **Intensity:** 6-8repetitionsofeachmovement using seven repetitions of maximum strength (7RM) **Sets:** Complete two sets of each movement **Frequency:** One or two sessions per week **Rest:** 60 seconds between sets	correlation with gait and no direct correlation with executive function.

3 Effects of resistance training movement patterns on cognitive functioning

3.1 Unstable plane resistance training

Unstable plane resistance training is a process that promotes the restoration of postural stability, which is defined as follows: when the body posture swings, the center of mass goes beyond the equipment support area or the reaction force changes the position of the center of pressure due to surface distortion (e.g., low-density foam pads, sand) [41]. Unlike traditional strength training, unstable plane resistance training focuses on both postural and core stability development [42-44]. Its main feature is the significant activation of stabilizing muscles. Compared with stable resistance training, unstable plane resistance training may pose a greater challenge to the neuromuscular system. It enhances the neural adaptations of stabilizing trunk muscles, which in turn improves core stability [45-47]. Unlike aerobic exercise, unstable plane resistance training shows more consistent positive effects on executive function [48,49]. Demanding unstable plane resistance training may include challenging eye-hand coordination, leg-arm coordination, and the ability to react to moving objects or people in various planes [49]. In addition, it may include responses to disturbances that require participants to remain stable in a sub-stable equilibrium state [48,50].

According to Cavalcante et al [51], a 12-week experiment was conducted with 67 older adults with a mean age of 71 years with cognitive deterioration of subjective function. The experiment was divided into a resistance training group and an unstable plane resistance training group. Movements in the unstable plane resistance training group included sand ball squats, dumbbell bench presses, leg presses, seated rope rows, bridges, calf raises, and curls, which were performed on an unstable plane or device. The workout was performed at an intensity of 10-15RM, with three sets of each movement performed three times per week with 60-90 seconds of rest between sets. The results of the study showed that the unstable plane resistance training

group did not show significant improvements in global cognitive tests, selective attention, inhibitory control, and processing speed.
However, the unstable plane resistance training group performed significantly better than the conventional resistance training group in terms of overall cognition and attention compared to the conventional resistance training group. In the study by Eckardt et al [52], a total of 68 healthy elderly people between the ages of 65-79 years participated in a 10-week experiment. The experiment consisted of unstable planar resistance training as well as stabilized multi-joint training and stabilized single-joint training. In the unstable plane resistance training group, the movements included unstable surface training, mechanical multi-joint training and mechanical wide abduction-adduction (single joint) training. The intensity of the training was 15RM, and each movement was gradually increased from 2 sets to 4 sets, and the training was performed twice a week. The experimental results showed that the unstable plane resistance training group was superior to the stable multi-joint and stable single-joint training groups in terms of working memory. The unstable plane resistance training group similarly outperformed the stable training group in terms of inhibitory control, selective attention and processing speed. These results further confirm the positive effects of unstable plane resistance training on cognitive function and attention in older adults. According to Silva-Batista [14], a total of 39 Parkinson's disease patients with a mean age of 65 years participated in a 12-week experiment. In the design of the resistance training group, the movements included leg presses, pulley pull-downs, ankle metatarsal flexion, chest presses, and half squats, while these movements were performed on an unstable plane or device. The training was performed at an intensity of 10-12RM or 6-8RM, progressively increasing from two to four sets of each movement, twice a week. The results of the study showed that compared to the control group, the group that participated in unstable plane resistance training showed significant improvement in Mentel Cognitive Assessment (MoCA) scores, quality of life, mobility, and exercise capacity, as well as a significant increase in muscle strength. This further demonstrates that unstable plane resistance training can improve the cognitive level and quality of life, as well as muscle strength of Parkinson's disease patients, and has a positive effect on their daily activities.

3.2 High-speed resistance training

As humans age, the deterioration of motor perceptual functions as well as the nervous system can lead to decreases in muscle strength, balance, and cognitive function. High-speed resistance training (HSRT), on the other hand, is considered to be an effective method for improving muscle strength in older adults [13].HSRT involves training with faster ($\leq$ 1 s) centripetal movements using lighter loads (i.e., 0%-60% of the one-repetition maximum 1RM) [53].
In contrast, traditional resistance training (TRT) involves intentionally maintaining a slower centripetal phase ($\geq$2 seconds) or not attempting to move the load as fast as possible [54]. Although a large number of studies have demonstrated that both traditional resistance training (TRT) and HSRT can help improve functional performance in older adults [55], HSRT has the advantage of tending to exert its effects more by enhancing neural adaptations rather than muscle fibre adaptations [56], and correlates more with performance in activities of daily living [57,58]. This is a significant contribution to quality of life, independence and health in older adults [59,60].

Coelho-Junior et al [6] conducted a 24-week study with 45 participants in healthy older women with a mean age of 67 years. In this study, resistance training movements included seated rowing, leg press machine, chest press machine, seated leg curl machine, side plank machine, calf raises, bicep curl machine, triceps lowering machine, and curls, all of which were paired with a high-speed centripetal elastic band. The intensity of the workout was set at 8-10RM, with three sets of each movement performed twice a week with a 60-second rest period between sets. The results of the study showed that high speed resistance training (HSRT) outperformed traditional resistance training and control group performance in terms of short-term memory and dual-task functioning. Coelho Junior and Uchida [61] conducted a 16-week study on frail and pre-frail older adults between the ages of 60 and 99 years old with a total of 60 participants. The resistance training practiced included movements such as chair squats (movement stroke: standing - hips touching the chair), unilateral hip flexion, unilateral knee extension and calf raises, which were performed in a high-speed centripetal burst. Training intensity was set at 3-5RM or 8-10RM, with four or eight sets of each movement performed, twice a week, with rest periods between sets not clearly defined. The results of the study showed that for pre-frail older adults, their frailty was significantly improved by HSRT training, while their language learning ability and auditory-linguistic ability were enhanced. In the frail older adults, their auditory-linguistic abilities were significantly improved by HSRT training compared to the control group.In addition, Yoon et al [62] conducted a 12-week resistance training experiment with 30 elderly women with mild cognitive impairment (MCI) at an average age of 76 years. The training in the study consisted of high-speed centripetal or low-speed centripetal movements using elastic bands, and the intensity of the training was set at either 12-15RM or 8-10RM. two to three sets of each movement were performed, with an ensured 60-second rest between sets and a 120-second rest when changing equipment, twice a week. The results of the study showed that high speed resistance training (HSRT) had a significant ameliorative effect on mild cognitive impairment in older women. Specifically, participants who performed HSRT outperformed those who performed slow resistance training and those in the control group on both Mini Mental State Examination (MMSE) scores and Montreal Cognitive Assessment (MoCA) scores.

From the above studies, High Speed Resistance Training (HSRT) has shown significant improvements in effectiveness in a variety of scenarios and populations. Studies in healthy older women have shown that HSRT can outperform traditional resistance training in short-term memory and dual-task functioning. In addition, HSRT in pre-frail older adults showed significant improvements in frailty status as well as verbal learning ability and auditory-verbal ability.

The training effect of HSRT was also significant in frail older adults, especially the improvement of auditory-verbal ability. For older women with mild cognitive impairment, HSRT also significantly improved their cognitive status. Overall, HSRT is an effective training tool for older adults with significant improvements in memory, dual-task function, language learning, and auditory-linguistic abilities.

3.3 Functional Resistance Training

In recent years, non-pharmacological interventions have been gaining attention as a possible means of improving cognitive performance in older adults [63]. Studies have shown that resistance training interventions have a positive effect on cognitive performance [64]. In addition to this, functional resistance training programs are increasingly being used in the field of cognitive decline research to improve general and specific cognitive performance in older adults [65]. Current emerging research is exploring the effects of combining cognitive training with resistance training on cognitive function [66]. Relevant studies have argued that this combination is justified because both types of interventions are closely linked to different mechanisms of brain plasticity [67]. Thus, resistance training and cognitive training may promote cognitive improvement through different brain plasticity mechanisms. The National Academy of Sciences has proposed that functional resistance training integrates cognitive and resistance training as the most effective way to improve and maintain cognitive function in older adults [24]. Studies have shown that interventions that combine cognitive and resistance training can help improve cognitive function in older adults [68,69].

In a study by David et al [70], functional resistance training (FR), a non-pharmacological intervention strategy, was performed over a two-year period in 38 middle-aged and elderly Parkinson's disease patients (mean age 59 years). Although the exact prescription for this training was not detailed, it is known to include strengthening exercises for all major muscle groups, with an emphasis on stretching, balance exercises, breathing, and non-gradual incremental low-intensity resistance training; information on the intensity of the training, the number of sets, and the rest periods between sets was not disclosed. The study setup was two training sessions per week. The results of the study showed that 12 months after resistance training, participants' levels of numerical memory were significantly improved, and inhibitory control and selective attention were superior to stepwise resistance training and baseline levels in the modified fitness program (mFC) condition. After completing 24 months of training, participants showed significant improvements in numerical attention, inhibitory control, selective attention, and Unified Parkinson's Rating Scale. With this 24-month resistance training, attention levels were superior to the mFC condition on the progressive resistance training. In addition, a significant positive correlation was found between breadth of digital memory and gait improvement.

Norouzi et al [71] conducted a four-week functional resistance training study with 60 healthy older men (mean age 68 years). Training in this study consisted of either integrated resistance training (combined with cognitive training) or low intensity training. The intensity of the training was set at 8RM, with the number of sets gradually increasing to exhaustion. A total of twelve sets were set at a frequency of two to three times per week, with 60 seconds of rest between sets. The results of the study showed that the motor-cognitive dual-task training (mCdtt) group had better working memory scores and balance test results than the motor-motor dual-task training (mMdtt) group and the control group. Similarly, the mCdtt group outperformed the mMdtt group and the control group on the 12-week return working memory test. The results confirm that functional resistance training, in conjunction with cognitive training or low-intensity training, can help to improve the quality of life of healthy older men and enhance their social and self-care abilities.

In summary, training modes and movements may be as important as the prescribed dose, regardless of the experimental population. Tomporowski and Pesce [9] noted that cognitive engagement and learning is one of the key factors in altering cognition, and this is particularly evident in exercise. More complex or challenging modes of resistance training may have greater benefits on the cognitive level, whether it is increasing the difficulty of the movements in the resistance training itself or simply incorporating cognitive themes. Even in unstable plane resistance training, where the training load (as opposed to intensity) is lower than in traditional resistance training, the training method can still produce greater positive effects than traditional resistance training, as long as the gradually increasing load is maintained and the same volume of training is maintained. In their study, Wilke et al [72] found that free weights used in conventional resistance training at the same intensity had a significant advantage for inhibitory control compared to mechanical training. This suggests that appropriate learning difficulty does not conflict with the prescribed dose. Thus, by increasing the challenge of resistance training through increased cognitive involvement, combined with appropriate dose prescriptions, trainers can receive both the "cognitive benefits of learning" and the "cognitive-physiological effects of resistance training". This is perhaps the most appropriate prescription for cognitive improvement. This approach is applicable to unstable plane resistance training, high speed resistance training, and functional resistance training.

Table 2: Statistics of studies on the effects of resistance training movement patterns on cognitive functioning

Author/Year	**Subject of intervention**	**Duration of intervention**	**Training programs**	**Main results**
Norouzi et al (2019)	60 healthy middle-aged and older men (average age 68)	4 weeks	**Movements:** Perform integrated resistance training (with cognitive training), or perform low intensity training **Intensity:** 8RM intensity, increasing every four sets until strength is depleted **Sets:** Twelve sets **Frequency:** Two to three times per week **Rest:** 60 seconds between sets	1、Working memory scores: the mCdtt group (centered working memory training group) outperformed the mMdtt group (multimodal working memory training group) and both outperformed the control group 2、Working memory at the 12-week return visit: the mCdtt group outperformed the mMdtt group and

				both outperformed the control group 3、Balance test: mCdtt group outperformed mMdtt group, both outperformed control group
Cavalcante et al(2020)	67 older adults with SCD (mean age 71)	12 weeks	**Movements:** Sand ball squats, barbell bench press, leg press, seated rope row, bridge, calf raises, curls, the above movements need to be performed on an unstable plane or device **Intensity:** Choose 10-15RM **Sets:** Three sets of each movement **Frequency:** Three times a week **Rest:** 60-90 seconds between sets	1、Global cognitive tests, selective attention, inhibitory control, and processing speed did not show significant changes after this intervention.
David et al (2015)	38 older adults with Parkinson's (mean age 59 years)	2 years	**Movements:** Prescription not yet described in detail, may include strengthening exercises for all major muscle groups, or focus on stretching, balance exercises, breathing and non-progressive low intensity resistance training. **Intensity:** Intensity not yet determined **Sets:** The number of	1、Improvement in number memory after 12 months 2、After 12 months, the mFC group (advanced prefrontal cortex power training) outperformed the progressive resistance training group and the baseline group in terms of inhibitory control and selective attention.

			sets is undetermined. **Frequency:** Two sessions per week **Rest :** Rest time between sets not yet determined	3、After 24 months, numerical attention, inhibitory control, selective attention, and the Unified Parkinson's Rating Scale improved 4、At 24 months, the progressive resistance training group was superior to the mFC group in terms of attention 5、Otherwise: significant positive correlation between improvement in digit breadth memory and gait
Eckardt et al (2020)	68 healthy older people (average age 72)	10 weeks	**Movements:** Including unstable surface training, mechanical multi-joint training and mechanical wide abduction and adduction (single joint) training **Intensity:** Set at 15RM Sets: Start with two sets of each movement and gradually increase to four sets as training progresses **Frequency:** Twice a week **Rest:** unknown	1、Working memory aspects: unstable surface training outperforms stable polyarticular and stable monoarticular training 2、Inhibitory control, selective attention, and processing speed: unstable surface training group outperforms stable training group
Yoon et al (2016)	30 older women with MCI (mean age 76)	12 weeks	**Movements:** High speed centripetal movement or low speed centripetal movement using	1、MMSE scores: the HSRT group (high speed resistance training) was better than the

			elastic band **Intensity:** Choose between 12-15RM or 8-10RM. **Sets:** Two to three sets of each movement. **Frequency:** Twice a week **Sets:** 60 seconds between sets, 120 seconds between equipment sets	slow speed resistance training group and both were better than the control group 2、MoCA score: the HSRT group (high speed resistance training) was superior to the slow speed resistance training group and the control group
Silva-Batista et al(2016)	39 middle-aged and older adults with Parkinson's (mean age 65 years)	12 weeks	**Movements:** Leg press, pulley pull down, ankle metatarsal flexion, chest press, half squat or the former, all on an unstable plane or device **Intensity:** Choose between 10-12RM or 6-8RM. **Sets:** Start with two sets of each movement and gradually increase until you reach four sets **Frequency:** Two sessions per week **Rest:** Unknown	1、For the MoCA score (Cognitive Functioning Score), quality of life, mobility, and exercise capacity, the results showed that the performance in the unstable plane group exceeded that of the control group 2、In terms of muscle strength, there was an increase in muscle strength after the intervention
Coelho Junior (2021)	60 frail and pre-frail older people (average age 80)	16 weeks	**Movements:** deep chair squats (squat to chair), unilateral hip flexion, unilateral knee extension, and calf raises. All of the above movements should be performed in a centripetal explosive manner	1、Among the pre-frail elderly, the intervention resulted in an increase in frailty status as well as language learning and auditory-linguistic skills 2、The HSRT group (High Speed

			Intensity: Intensity can be chosen in the range of 3-5RM or 8-10RM **Sets:** Eight or four sets of each movement depending on demand **Frequency:** Twice a week **Rest:** unknown	Resistance Training) was more effective than the control group in terms of auditory-linguistic ability in the frail elderly.

Coelho Junior et al(2020)	45 healthy older women (mean age 67)	24 weeks	**Movements:** seated rowing, leg press machine, chest press machine, seated leg curl machine, side plank machine, calf raises, bicep curl machine, triceps lowering machine and curls, all of the above movements should be performed with elastic bands at high speed centripetally **Intensity:** The intensity should be set in the range of 8-10RM. **Sets:** Three sets of each movement. **Frequency:** Twice a week **Rest:** 60 seconds between sets.	1、For short-term memory and dual-task functional performance, the HSRT group (high-speed resistance training) outperformed the traditional resistance training group as well as the baseline level

Table notes: mFC: modified fitness program, mMdtt: motor-exercise dual-task training, mCdtt: motor-cognitive dual-task training, SCD: subjective cognitive deterioration, MCI: mild cognitive impairment

4 Conclusion and outlook

4.1 Conclusion

(1) For older adults, especially older women, long-term participation in twice-weekly resistance training significantly maintains or even improves executive function, memory capacity, and brain volume, and these benefits are likely to be retained after training is terminated. Meanwhile, for the middle-aged and older population, progressive resistance training with moderate or higher intensity may have positive effects on cognitive function and physical fitness, but an increase in training volume up to a certain point may lead to a decline in improvement benefits. In addition, for groups suffering from mild cognitive impairment, this type of training may also help to mitigate the degradation of hippocampal gyrus volume in the brain.

(2) Unstable plane resistance training and high-speed resistance training are more effective than traditional resistance training in improving cognitive function due to the challenging and complex nature of the content and movements and the greater involvement of brain work. This type of training has also shown its particular benefits in terms of improvement in auditory-verbal function by stimulating type II muscle fibres and requiring higher neurological involvement.

(3) The engagement of cognitive and learned behaviours in functional resistance training creates complex and challenging training within the training, resulting in greater benefits for improving cognitive function. Exploiting the dual effects of learning and resistance training is an effective targeted strategy for improving cognitive function.

4.2 Outlook

(1) Existing studies have mostly focused on training 2-3 times per week and less on higher training volumes. Although the relationship between exercise intensity and cognition may be non-linear, the relationship between higher training volume and optimal prescription needs to be explored in the future. In the meantime, the definition of intensity needs to be further clarified, and factors such as load and repetitions need to be considered in more detail to accurately plan prescription design.

(2) Existing research suggests that resistance training can take many forms, but there is limited research on unstable-plane, high-speed, functional resistance training. These types of resistance training require more attention and muscle involvement or may be useful for cognitive enhancement. Future research directions suggest comparing free weight versus machine-based training, as well as circuit, functional, and traditional resistance training to identify differences between training protocols.

(3) Resistance training can enhance cognitive function and muscle strength. Future studies should further explore the relationship between resistance training and the two, and apply muscle fitness in the assessment of resistance training benefits to further understand the mechanism of action of resistance training.

References

1. ERICKSON K I, HILLMAN C, STILLMAN C M, et al. Physical Activity, Cognition, and Brain Outcomes: A Review of the 2018 Physical Activity Guidelines [J/OL]. Medicine & Science in Sports & Exercise, 2019, 51(6): 1242-1251. DOI:10.1249/MSS.000000000000 1936.
2. COX E P, O'DWYER N, COOK R, et al. Relationship between physical activity and cognitive function in apparently healthy young to middle-aged adults: A systematic review [J/OL]. Journal of Science and Medicine in Sport, 2016, 19(8): 616-628. DOI:10.1016/j.jsams.2015.09.003.
3. BECKETT M W, ARDERN C I, ROTONDI M A. A meta-analysis of prospective studies on the role of physical activity and the prevention of Alzheimer's disease in older adults [J/OL]. BMC Geriatrics, 2015, 15(1): 9. DOI:10.1186/s12877-015-0007-2.
4. LANDRIGAN J F, BELL T, CROWE M, et al. Lifting cognition: a meta-analysis of effects of resistance exercise on cognition [J/OL]. Psychological Research, 2020, 84(5): 11671183. DOI:10.1007/s00426-019-01145-x.
5. SOGA K, MASAKI H, GERBER M, et al. Acute and Long-term Effects of Resistance Training on Executive Function [J/OL]. Journal of Cognitive Enhancement, 2018, 2(2): 200 -207. DOI:10.1007/s41465-018-0079-y.
6. COELHO-JÚNIOR H J, OLIVEIRA GONÇALVES I D, SAMPAIO R A C, et al. Effects of Combined Resistance and Power Training on Cognitive Function in Older Women: A Randomized Controlled Trial [J/OL]. International Journal of Environmental Research and Public Health, 2020, 17(10): 3435. DOI:10.3390/ijerph17103435.
7. KJØLHEDE T, SIEMONSEN S, WENZEL D, et al. Can resistance training impact MRI outcomes in relapsing-remitting multiple sclerosis? [J/OL]. Multiple Sclerosis Journal, 201 8, 24(10): 1356-1365. DOI:10.1177/1352458517722645.
8. TSAI C L, WANG C H, PAN C Y, et al. The effects of long-term resistance exercise on the relationship between neurocognitive performance and GH, IGF-1, and homocysteine levels in the elderly [J/OL]. Frontiers in Behavioral Neuroscience, 2015, 9[2023-11-13]. http://journal.frontiersin.org/Article/10.3389/fnbeh.2015.00023/abstract. DOI:10.3389/fnbeh.2015.0 0023.
9. TOMPOROWSKI P D, PESCE C. Exercise, sports, and performance arts benefit cognition via a common process. [J/OL]. Psychological Bulletin, 2019, 145(9): 929-951. DOI:10.1 037/bul0000200.
10. LI Z, PENG X, XIANG W, et al. The effect of resistance training on cognitive function on in the older adults: a systematic review of randomized clinical trials[J/OL]. Aging Clinical and Experimental Research, 2018, 30(11): 1259-1273. DOI:10.1007/s40520-018-0998-6.
11. [11] FERNANDEZ-GONZALO R, FERNANDEZ-GONZALO S, TURON M, et al. Muscle, functional and cognitive adaptations after flywheel resistance training in stroke patients: a pilot randomized controlled trial[J/OL]. Journal of Neuro Engineering and Rehabilitation, 201 6, 13(1): 37. DOI:10.1186/s12984-016-0144-7.
12. [12] FORMA L, RISSANEN P, AALTONEN M, et al. Dementia as a determinant of social and health service use in the last two years of life 1996-2003[J/OL]. BMC geriatrics, 201 1, 11: 14. DOI:10.1186/1471-2318-11-14.

13. [13] MARTINS A D, FERNANDES O, PEREIRA A, et al. The Effects of High-Speed Resistance Training on Health Outcomes in Independent Older Adults: A Systematic Review and Meta-Analysis[J/OL]. International Journal of Environmental Research and Public Health, 2022, 19(9): 5390. DOI:10.3390/ijerph19095390.
14. [14] SILVA-BATISTA C, CORCOS D M, ROSCHEL H, et al. Resistance Training with Instability for Patients with Parkinson's Disease[J/OL]. Medicine & Science in Sports & Exercise, 2016, 48(9): 1678-1687. DOI:10.1249/MSS.0000000000000945.
15. [15] NICOLA F, CATHERINE S. Dose–response relationship of resistance training in older adults: a meta-analysis[J/OL]. British Journal of Sports Medicine, 2011, 45(3): 233-234. DOI:10.1136/bjsm.2010.083246.
16. [16] WJ K, NA R, DN F. Resistance training for health and performance[J/OL]. Current sports medicine reports, 2002, 1(3)[2023-11-14]. https://pubmed.ncbi.nlm.nih.gov/12831709/. DOI:10.1249/00149619-200206000-00007.
17. [17] KRAEMER W J, DESCHENES M R, FLECK S J. Physiological Adaptations to
18. Resistance Exercise: Implications for Athletic Conditioning[J/OL]. Sports Medicine, 1988, 6(4): 2 46-256. DOI:10.2165/00007256-198806040-00006.
19. [18] MEEUSEN R, DUCLOS M, FOSTER C, et al. Prevention, diagnosis and treatment of the overtraining syndrome: Joint consensus statement of the European College of Sport Science (ECSS) and the American College of Sports Medicine (ACSM)[J/OL]. European Journal of Sport Science, 2013, 13(1): 1-24. DOI:10.1080/17461391.2012.730061.
20. [19] COELHO J Hélio José, RODRIGUES B, DE OLIVEIRA GONÇALVES I, et al. Effects of a short-term detraining period on muscle functionality and cognition of strength-trained older women : a preliminary report[J/OL]. Journal of exercise rehabilitation, 2017, 13(5): 559-567. DOI:10.12965/jer.1735010.505.
21. [20] FALLAH N, HSU C L, BOLANDZADEH N, et al. A multistate model of cognitive dynamics in relation to resistance training: the contribution of baseline function[J/OL]. Annals of Epidemiology, 2013, 23(8): 463-468. DOI:10.1016/j.annepidem.2013.05.008.
22. [21] LIU-AMBROSE T. Resistance Training and Executive Functions: A 12-Month Randomized Controlled Trial[J/OL]. Archives of Internal Medicine, 2010, 170(2): 170. DOI:10.1001/ archinternmed.2009.494.
23. [22] BEST J R, CHIU B K, LIANG HSU C, et al. Long-Term Effects of Resistance Exercise Training on Cognition and Brain Volume in Older Women: Results from a RandomizedControlled Trial[J/OL]. Journal of the International Neuropsychological Society, 2015, 21(1 0): 745-756. DOI:10.1017/S1355617715000673.
24. [23] BOLANDZADEH N, TAM R, HANDY T C, et al. Resistance Training and White Matter Lesion Progression in Older Women: Exploratory Analysis of a 12-Month Randomized Controlled Trial[J/OL]. Journal of the American Geriatrics Society, 2015, 63(10): 2052-206 0. DOI:10.1111/jgs.13644.
25. [24] SPRAGUE B N, FREED S A, WEBB C E, et al. The impact of behavioral interventions on cognitive function in healthy older adults: A systematic review[J/OL]. Ageing Research Reviews, 2019, 52: 32-52. DOI:10.1016/j.arr.2019.04.002.
26. [25] AINSWORTH B E, HASKELL W L, WHITT M C, et al. Compendium of Physical

27. Activities: an update of activity codes and MET intensities:[J/OL]. Medicine & Science in S ports & Exercise, 2000, 32(Supplement): S498-S516. DOI:10.1097/00005768-200009001-000 09.
28. [26] GARBER C E, BLISSMER B, DESCHENES M R, et al. Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory, Musculoskeletal, and Neuromotor Fitness in Apparently Healthy Adults: Guidance for Prescribing Exercise[J/OL]. Medicine & Science in Sports & Exercise, 2011, 43(7): 1334-1359. DOI:10.1249/MSS.0b013e318213fefb.
29. [27] FYFE J J, HAMILTON D L, DALY R M. Minimal-Dose Resistance Training for Improving Muscle Mass, Strength, and Function: A Narrative Review of Current Evidence and Practical Considerations[J/OL]. Sports Medicine, 2022, 52(3): 463-479. DOI:10.1007/s40279021-01605-8.
30. [28] MARSTON K J, PEIFFER J J, NEWTON M J, et al. A comparison of traditional and novel metrics to quantify resistance training[J/OL]. Scientific Reports, 2017, 7(1): 5606. D OI:10.1038/s41598-017-05953-2.
31. [29] CASSILHAS R C, VIANA V A R, GRASSMANN V, et al. The Impact of Resistance Exercise on the Cognitive Function of the Elderly[J/OL]. Medicine & Science in Sports & Exercise, 2007, 39(8): 1401-1407. DOI:10.1249/mss.0b013e318060111f.
32. [30] MARSTON K J, PEIFFER J J, RAINEY-SMITH S R, et al. Resistance training enhances delayed memory in healthy middle-aged and older adults: A randomised controlled trial [J/OL]. Journal of Science and Medicine in Sport, 2019, 22(11): 1226-1231. DOI:10.1016/j. jsams.2019.06.013.
33. [31] SCHOENFELD B J, GRGIC J. Effects of range of motion on muscle development during resistance training interventions: A systematic review[J/OL]. SAGE Open Medicine, 202 0, 8: 205031212090155. DOI:10.1177/2050312120901559.
34. [32] BAZ-VALLE E, FONTES-VILLALBA M, SANTOS-CONCEJERO J. Total Number of Sets as a Training Volume Quantification Method for Muscle Hypertrophy: A Systematic Review[J/OL]. Journal of Strength and Conditioning Research, 2021, 35(3): 870-878. DOI:10. 1519/JSC.0000000000002776.
35. [33] ISRAETEL M, FEATHER J, FALEIRO T V, et al. Mesocycle Progression in Hypertrophy: Volume Versus Intensity[J/OL]. Strength & Conditioning Journal, 2020, 42(5): 2-6. DOI:10.1519/SSC.0000000000000518.
36. [34] TOIGO M, BOUTELLIER U. New fundamental resistance exercise determinants of molecular and cellular muscle adaptations[J/OL]. European Journal of Applied Physiology, 200 6, 97(6): 643-663. DOI:10.1007/s00421-006-0238-1.
37. [35] FIGUEIREDO V C, DE SALLES B F, TRAJANO G S. Volume for Muscle Hypertrophy and Health Outcomes: The Most Effective Variable in Resistance Training[J/OL]. Sports Medicine, 2018, 48(3): 499-505. DOI:10.1007/s40279-017-0793-0.
38. [36] OLIFF H S, BERCHTOLD N C, ISACKSON P, et al. Exercise-induced regulation of brain-derived neurotrophic factor (BDNF) transcripts in the rat hippocampus[J/OL]. Molecular Brain Research, 1998, 61(1-2): 147-153. DOI:10.1016/S0169-328X(98)00222-8.

39. [37] FORTES L D S, COSTA M D C, PERRIER-MELO R J, et al. Effect of Volume in Resistance Training on Inhibitory Control in Young Adults: A Randomized and Crossover Investigation[J/OL]. Frontiers in Psychology, 2018, 9: 2028. DOI:10.3389/fpsyg.2018.02028.
40. [38] FORTES L S, COSTA M C, FERREIRA M E C, et al. Frequency of resistance training does not affect inhibitory control or improve strength in well-trained young adults[J/OL]. PLOS ONE, 2018, 13(11): e0206784. DOI:10.1371/journal.pone.0206784.
41. [39] STILLMAN C M, ESTEBAN-CORNEJO I, BROWN B, et al. Effects of Exercise on Brain and Cognition Across Age Groups and Health States[J/OL]. Trends in Neurosciences, 2020, 43(7): 533-543. DOI:10.1016/j.tins.2020.04.010.
42. [40] GALLARDO-GÓMEZ D, DEL POZO-CRUZ J, NOETEL M, et al. Optimal dose and type of exercise to improve cognitive function in older adults: A systematic review and bayesian model-based network meta-analysis of RCTs[J/OL]. Ageing Research Reviews, 2022, 76: 101591. DOI:10.1016/j.arr.2022.101591.
43. [41] BEHM D G, DRINKWATER E J, WILLARDSON J M, et al. The use of instability to train the core musculature[J/OL]. Applied Physiology, Nutrition, and Metabolism, 2010, 3 5(1): 91-108. DOI:10.1139/H09-127.
44. [42] GRANACHER U, SCHELLBACH J, KLEIN K, et al. Effects of core strength training using stable versus unstable surfaces on physical fitness in adolescents: a randomized controlled trial[J/OL]. BMC Sports Science, Medicine and Rehabilitation, 2014, 6(1): 40. DOI:1 0.1186/2052-1847-6-40.
45. [43] MARSHALL P W, MURPHY B A. Core stability exercises on and off a Swiss ball[J/OL]. Archives of Physical Medicine and Rehabilitation, 2005, 86(2): 242-249. DOI:10.1016 /j.apmr.2004.05.004.
46. [44] BEHM D G, DRINKWATER E J, WILLARDSON J M, et al. The Role of Instability Rehabilitative Resistance Training for the Core Musculature[J/OL]. Strength and Conditioning Journal, 2011, 33(3): 72-81. DOI:10.1519/SSC.0b013e318213af91.
47. [45] COSIO-LIMA L M, REYNOLDS K L, WINTER C, et al. Effects of Physio ball and Conventional Floor Exercises on Early Phase Adaptations in Back and Abdominal Core Stability and Balance in Women[J/OL]. The Journal of Strength and Conditioning Research, 20 03, 17(4): 721. DOI:10.1519/1533-4287(2003)017<0721:EOPACF>2.0.CO;2.
48. [46] STANTON R, REABURN P R, HUMPHRIES B. The Effect of Short-Term Swiss Ball Training on Core Stability and Running Economy[J/OL]. The Journal of Strength and Conditioning Research, 2004, 18(3): 522. DOI:10.1519/1533-4287(2004)18<522:TEOSSB>2.0.CO;2.
49. [47] CUĞ M, AK E, ÖZDEMIR R A, et al. The Effect of Instability Training on Knee Joint Proprioception and Core Strength[J]. Journal of Sports Science & Medicine, 2012, 11(3):
50. 468-474.
51. [48] ROGGE A K, RÖDER B, ZECH A, et al. Balance training improves memory and spa tial cognition in healthy adults[J/OL]. Scientific Reports, 2017, 7(1): 5661. DOI:10.1038/s4 1598-017-06071-9.
52. [49] VOELCKER-REHAGE C, GODDE B, STAUDINGER U M. Cardiovascular and Coordination Training Differentially Improve Cognitive Performance and Neural

Processing in Ol der Adults[J/OL]. Frontiers in Human Neuroscience, 2011, 5[2023-11-15]. http://journal.frontiersin.org/article/10.3389/fnhum.2011.00026/abstract. DOI:10.3389/fnhum.2011.00026.

53. [50] KIBELE A, GRANACHER U, MUEHLBAUER T, et al. Stable, Unstable and Metastable States of Equilibrium: Definitions and Applications to Human Movement[J]. Journal of Sports Science & Medicine, 2015, 14(4): 885-887.
54. [51] CAVALCANTE B R, DE SOUZA M F, FALCK R S, et al. Effects of Resistance Exercise with Instability on Cognitive Function (REI Study): A Proof-Of-Concept Randomized Controlled Trial in Older Adults with Cognitive Complaints[J/OL]. Journal of Alzheimer's Disease, 2020, 77(1): 227-239. DOI:10.3233/JAD-200349.
55. [52] ECKARDT N, BRAUN C, KIBELE A. Instability Resistance Training improves Working Memory, Processing Speed and Response Inhibition in Healthy Older Adults: A Double Blinded Randomized Controlled Trial[J/OL]. Scientific Reports, 2020, 10(1): 2506. DOI:10. 1038/s41598-020-59105-0.
56. [53] EARLES D R, JUDGE J O, GUNNARSSON O T. Velocity training induces power-specific adaptations in highly functioning older adults[J/OL]. Archives of Physical Medicine an d Rehabilitation, 2001, 82(7): 872-878. DOI:10.1053/apmr.2001.23838.
57. [54] FIELDING R A, LEBRASSEUR N K, CUOCO A, et al. High-Velocity Resistance Training Increases Skeletal Muscle Peak Power in Older Women[J/OL]. Journal of the American Geriatrics Society, 2002, 50(4): 655-662. DOI:10.1046/j.1532-5415.2002.50159.x.
58. [55] PAPA E V, DONG X, HASSAN M. Resistance training for activity limitations in older adults with skeletal muscle function deficits: a systematic review[J/OL]. Clinical Interventions in Aging, 2017, 12: 955-961. DOI:10.2147/CIA.S104674.
59. [56] CLAFLIN D R, LARKIN L M, CEDERNA P S, et al. Effects of high- and low-velocity resistance training on the contractile properties of skeletal muscle fibers from young an d older humans[J/OL]. Journal of Applied Physiology, 2011, 111(4): 1021-1030. DOI:10.115 2/japplphysiol.01119.2010.
60. [57] MD J F B, KIELY D K, HERMAN S, et al. The Relationship Between Leg Power and Physical Performance in Mobility-Limited Older People[J/OL]. Journal of the American Geriatrics Society, 2002, 50(3): 461-467. DOI:10.1046/j.1532-5415.2002.50111.x.
61. [58] FOLDVARI M, CLARK M, LAVIOLETTE L C, et al. Association of Muscle Power With Functional Status in Community-Dwelling Elderly Women[J/OL]. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 2000, 55(4): M192-M199. DOI:10.1093/gerona/55.4.M192.
62. [59] HAZELL T, KENNO K, JAKOBI J. Functional Benefit of Power Training for Older Adults[J/OL]. Journal of Aging and Physical Activity, 2007, 15(3): 349-359. DOI:10.1123/japa.15.3.349.
63. [60] CASEROTTI P. Strength Training in Older Adults: Changes in Mechanical Muscle Function and Functional Performance~!2009-07-05~!2009-11-01~!2010-04-29~![J/OL]. The Open Sports Sciences Journal, 2010, 3(1): 62-66. DOI:10.2174/1875399X01003010062.

64. [61] COELHO-JÚNIOR H J, UCHIDA M C. Effects of Low-Speed and High-Speed Resistance Training Programs on Frailty Status, Physical Performance, Cognitive Function, and Blood Pressure in Prefrail and Frail Older Adults[J/OL]. Frontiers in Medicine, 2021, 8: 702 436. DOI:10.3389/fmed.2021.702436.
65. [62] YOON D H, KANG D, KIM H, et al. Effect of elastic band-based high-speed power training on cognitive function, physical performance and muscle strength in older women with mild cognitive impairment[J/OL]. Geriatrics & Gerontology International, 2017, 17(5):765-772. DOI:10.1111/ggi.12784.
66. [63] LIVINGSTON G, HUNTLEY J, SOMMERLAD A, et al. Dementia prevention, intervention, and care: 2020 report of the Lancet Commission[J/OL]. The Lancet, 2020, 396(1024 8): 413-446. DOI:10.1016/S0140-6736(20)30367-6.
67. [64] BOGATAJ Š, MESARIČ K K, PAJEK M, et al. Physical exercise and cognitive training interventions to improve cognition in hemodialysis patients: A systematic review[J/OL]. Frontiers in Public Health, 2022, 10: 1032076. DOI:10.3389/fpubh.2022.1032076.
68. [65] HILL N T M, MOWSZOWSKI L, NAISMITH S L, et al. Computerized Cognitive Training in Older Adults With Mild Cognitive Impairment or Dementia: A Systematic Review and Meta-Analysis[J/OL]. American Journal of Psychiatry, 2017, 174(4): 329-340. DOI:1 0.1176/appi.ajp.2016.16030360.
69. [66] BHERER L, GAGNON C, LANGEARD A, et al. Synergistic Effects of Cognitive Training and Physical Exercise on Dual-Task Performance in Older Adults[J/OL]. The Journals of Gerontology: Series B, 2021, 76(8): 1533-1541. DOI:10.1093/geronb/gbaa124.
70. [67] FABEL K. Additive effects of physical exercise and environmental enrichment on adult hippocampal neurogenesis in mice[J/OL]. Frontiers in Neuroscience, 2009[2023-11-19]. http://journal.frontiersin.org/article/10.3389/neuro.22.002.2009/abstract.DOI:10.3389/neuro.22.002. 2009.
71. [68] HE Y, YANG L, ZHOU J, et al. Dual-task training effects on motor and cognitive functional abilities in individuals with stroke: a systematic review[J/OL]. Clinical Rehabilitation, 2018, 32(7): 865-877. DOI:10.1177/0269215518758482.
72. [69] RAHE J, PETRELLI A, KAESBERG S, et al. Effects of cognitive training with additional physical activity compared to pure cognitive training in healthy older adults[J/OL]. Clinical Interventions in Aging, 2015: 297. DOI:10.2147/CIA.S74071.
73. [70] DAVID F J, ROBICHAUD J A, LEURGANS S E, et al. Exercise improves cognition in Parkinson's disease: The PRET-PD randomized, clinical trial: Exercise Improves Cognition IN PD[J/OL]. Movement Disorders, 2015, 30(12): 1657-1663. DOI:10.1002/mds.26291.
74. [71] NOROUZI E, VAEZMOSAVI M, GERBER M, et al. Dual-task training on cognition and resistance training improved both balance and working memory in older people[J/OL]. The Physician and Sports medicine, 2019, 47(4): 471-478. DOI:10.1080/00913847.2019.1623 996.
75. [72] WILKE J, STRICKER V, USEDLY S. Free-Weight Resistance Exercise Is More Effective in Enhancing Inhibitory Control than Machine-Based Training: A Randomized,

Controlled Trial[J/OL]. Brain Sciences, 2020, 10(10): 702. DOI:10.3390/brainsci10100702.