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THE RELATIONSHIP BETWEEN MUSCLE STRENGTH, PHYSICAL ACTIVITY LEVEL, AND FUNCTIONAL INDEPENDENCE IN OLDER ADULTS: A NARRATIVE REVIEW

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Abstract: Population aging is associated with progressive declines in muscle strength, physical performance, and overall functional capacity. Maintaining functional independence is a primary goal of healthy aging because it directly influences quality of life, healthcare utilization, and social participation. Growing evidence indicates that muscle strength and physical activity are among the strongest determinants of independent functioning in later life. To review current evidence regarding the relationship between muscle strength, physical activity level, and functional independence among older adults and to discuss the underlying physiological mechanisms and clinical implications. A narrative review was conducted using literature retrieved from PubMed, Scopus, Web of Science, Google Scholar, and international public health databases. Priority was given to systematic reviews, meta-analyses, randomized controlled trials, and cohort studies published between 2020 and 2025. Thematic synthesis was performed to evaluate the influence of muscle strength and physical activity on functional independence. Current evidence consistently demonstrates that muscle strength is a major predictor of functional independence in older adults. Higher levels of physical activity are associated with improved muscle function, mobility, balance, and performance of activities of daily living. Resistance training appears particularly effective in preserving functional capacity by enhancing muscular strength and reducing the risk of disability. Handgrip strength and lower-extremity strength are strongly associated with mobility, fall prevention, and independent living. Muscle strength and physical activity represent fundamental determinants of functional independence in older adults. Strategies aimed at increasing participation in physical activity, particularly resistance training, may contribute significantly to healthy aging and prevention of disability.

Keywords: Aging, muscle strength, physical activity, functional independence, healthy aging, resistance training, sarcopenia.

Introduction

Population aging has become one of the most significant demographic transformations of the twenty-first century. According to the World Health Organization, healthy aging is not merely the absence of disease but rather the preservation of functional ability and autonomy throughout later life [8,9]. Functional independence, defined as the capacity to perform activities of daily living without external assistance, is considered one of the principal indicators of successful aging and quality of life [8,9]. Maintaining independence allows older adults to remain socially engaged, reduces healthcare expenditures, decreases institutionalization rates, and contributes substantially to psychological well-being [8,9]. Physically active older adults demonstrate higher levels of muscular fitness, superior



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functional health, lower fall risk, and better preservation of independent living capacities [8,9,19].

The decline in physical functioning observed with advancing age is multifactorial. Physiological aging is characterized by reductions in skeletal muscle mass, neuromuscular efficiency, mitochondrial function, endocrine regulation, and regenerative capacity [10,17,23]. These alterations contribute to sarcopenia, a progressive syndrome involving the loss of muscle strength and physical performance [10,17]. Contemporary research increasingly recognizes that muscle strength, rather than muscle mass alone, represents the most clinically relevant predictor of disability, morbidity, and mortality in older populations [10,12,17].

Physical activity has emerged as one of the most effective non-pharmacological strategies for counteracting age-related functional decline [15,18,19]. Numerous epidemiological investigations have demonstrated that physically active older adults maintain superior mobility, balance, cardiovascular health, metabolic regulation, and cognitive function compared with sedentary individuals [4,7,15,18]. However, the exact pathways through which physical activity contributes to functional independence remain an area of active investigation. Recent evidence suggests that improvements in muscle strength may mediate a substantial proportion of the beneficial effects of physical activity on functional outcomes [2,4,7,15].

Although a growing body of literature has independently examined muscle strength or physical activity in older adults, fewer reviews have specifically analyzed the dynamic interaction among muscle strength, physical activity levels, and functional independence [1,2,4]. Understanding these relationships is essential for developing targeted interventions that maximize healthy aging and prevent disability.

The purpose of this review is therefore to critically examine current evidence regarding the interrelationship between muscle strength, physical activity level, and functional independence in older adults while exploring the physiological mechanisms that underlie these associations and their implications for clinical practice and public health policy.

Methods

A comprehensive literature search was performed using PubMed, Scopus, Web of Science, Google Scholar, and international public health databases. Priority was given to systematic reviews, meta-analyses, randomized controlled trials, and prospective cohort studies published between 2020 and 2025.

The search strategy incorporated combinations of the keywords "older adults", "aging", "muscle strength", "physical activity", "functional independence", "activities of daily living", "sarcopenia", "frailty", and "resistance training". Eligible studies included adults aged 60 years or older and reported outcomes related to muscle strength, physical activity, physical function, mobility, disability, or independence.

The collected literature was analyzed using a thematic synthesis approach. Evidence was categorized according to four major domains: age-related decline in

muscle strength, relationship between strength and independence, effects of physical activity on functional outcomes, and physiological mechanisms linking physical activity, muscular strength, and functional independence.

Results

Muscle Strength and Functional Independence. The analysis of contemporary literature revealed a highly consistent relationship among muscle strength, physical activity participation, and functional independence in later life. Across observational studies, longitudinal cohorts, randomized controlled trials, and systematic reviews, muscle strength emerged as one of the most important determinants of successful aging and the preservation of independent living.

One of the most significant findings emerging from recent evidence is that muscle strength is repeatedly identified as one of the strongest predictors of physical independence. In the systematic review and meta-analysis conducted by Miri et al., which included 5,733 older adults, handgrip strength, lower-extremity strength, muscle function, aerobic endurance, knee extension power, and physical activity levels were all significantly associated with functional independence [1]. The authors reported that individuals with greater muscular performance consistently demonstrated higher physical independence scores and lower risks of functional dependence.

The relationship between muscle strength and independence can be explained through the demands imposed by activities of daily living. Most routine tasks including standing from a seated position, walking, carrying objects, climbing stairs, maintaining balance, and recovering from perturbations require adequate lower-limb and trunk muscle force. Consequently, reductions in muscular strength directly compromise the ability to perform these activities independently.

Handgrip strength has been extensively investigated as a practical marker of overall health status. Numerous cohort studies have demonstrated that lower handgrip strength predicts disability, hospitalization, institutionalization, frailty, and all-cause mortality [11,12]. Furthermore, handgrip strength has been shown to reflect not only upper-extremity function but also general neuromuscular capacity and physiological reserve.

Recent evidence suggests that lower-extremity strength may have an even stronger relationship with independence than handgrip strength. Older adults with higher quadriceps and hip extensor strength consistently demonstrate superior gait speed, better balance performance, greater mobility, and improved performance during chair-rise tests [23,25]. These findings support the notion that maintaining lower-body strength is essential for functional autonomy.

A particularly important observation is that muscle strength often predicts future disability independently of age, sex, body composition, and disease status. Therefore, strength should not be viewed merely as a consequence of healthy aging but rather as an independent predictor of future functional outcomes.

Physical Activity as a Determinant of Functional Performance. Physical activity was consistently associated with superior functional outcomes across the reviewed literature. Older adults who engaged in regular physical activity

demonstrated higher mobility levels, superior balance performance, greater muscular fitness, and reduced risk of disability compared with sedentary counterparts [4,7,15].

The positive relationship between physical activity and functional independence has been documented across different populations, including community-dwelling individuals, frail adults, residential care residents, and institutionalized populations. The consistency of findings across such diverse groups suggests that physical activity remains beneficial throughout the aging continuum.

The recent systematic review by Miri et al. identified physical activity as one of the strongest correlates of physical independence [1]. Similarly, Wickramarachchi et al. demonstrated that physically active individuals exhibited superior physical fitness, balance, strength, and functional abilities compared with less active peers [7].

Physical activity appears to influence independence through multiple pathways. Aerobic activities improve cardiovascular function and endurance, whereas resistance exercises increase muscular strength and power. Additional benefits include improvements in balance, coordination, flexibility, and psychological well-being. Collectively, these adaptations facilitate independent performance of everyday tasks and reduce vulnerability to disability.

Importantly, evidence indicates that sedentary behavior itself constitutes an independent risk factor for functional decline. Older adults who spend prolonged periods sitting demonstrate accelerated losses in muscular performance, reduced mobility, increased frailty, and greater risk of institutionalization. Thus, reducing sedentary behavior may be nearly as important as promoting structured exercise interventions.

Resistance Training and Functional Independence. Among all forms of physical activity, resistance training demonstrated the strongest and most consistent effects on muscle strength and functional performance.

Meta-analytic evidence indicates that resistance exercise significantly increases handgrip strength, lower-limb strength, walking speed, balance capacity, stair-climbing performance, and physical functioning [2,6,13]. These improvements are clinically meaningful because each of these parameters is strongly associated with the ability to maintain independent living.

The 2024 meta-analysis by Choi et al. reported significant beneficial effects of resistance training on multiple frailty-related outcomes, including handgrip strength, lower-limb strength, balance, and gait speed [2]. Similar findings were reported by Kirk et al., who demonstrated that machine-based resistance training significantly improved both strength and functional capacity among adults older than sixty years [3].

One particularly notable finding is that substantial physiological benefits can be achieved even among very old adults. Earlier work by Fiatarone et al. demonstrated that individuals older than ninety years remained capable of achieving significant strength gains following structured resistance training [22]. These findings challenge longstanding assumptions that functional decline in advanced age is inevitable and irreversible.

Furthermore, evidence suggests that resistance training contributes to improvements in confidence, self-efficacy, and participation in community activities. Consequently, its effects extend beyond physiological outcomes and influence broader domains of quality of life.

Physical Activity, Strength, and Frailty. Frailty is increasingly recognized as a major public health concern in aging populations. The syndrome is characterized by diminished physiological reserve and increased vulnerability to adverse health outcomes.

Muscle weakness is one of the core components of frailty [16,17]. Consequently, interventions capable of improving muscle strength may play a crucial role in preventing or reversing frailty-related declines.

Several studies included in this review demonstrated significant reductions in frailty severity following structured exercise interventions [2,4,16]. Gains in strength were frequently accompanied by improvements in mobility, balance, and performance of activities of daily living, suggesting that muscular adaptations contribute directly to enhanced resilience.

The relationship between frailty and physical activity appears bidirectional. Reduced activity contributes to muscle weakness and frailty, whereas frailty often results in further reductions in physical activity levels. This creates a self-perpetuating cycle that accelerates functional decline. Exercise interventions, particularly those incorporating resistance training, may interrupt this cycle and promote functional recovery.

Proposed Mechanistic Pathway. Based on the reviewed literature, the relationship among physical activity, muscle strength, and independence can be conceptualized as a sequential physiological pathway (Figure 1):

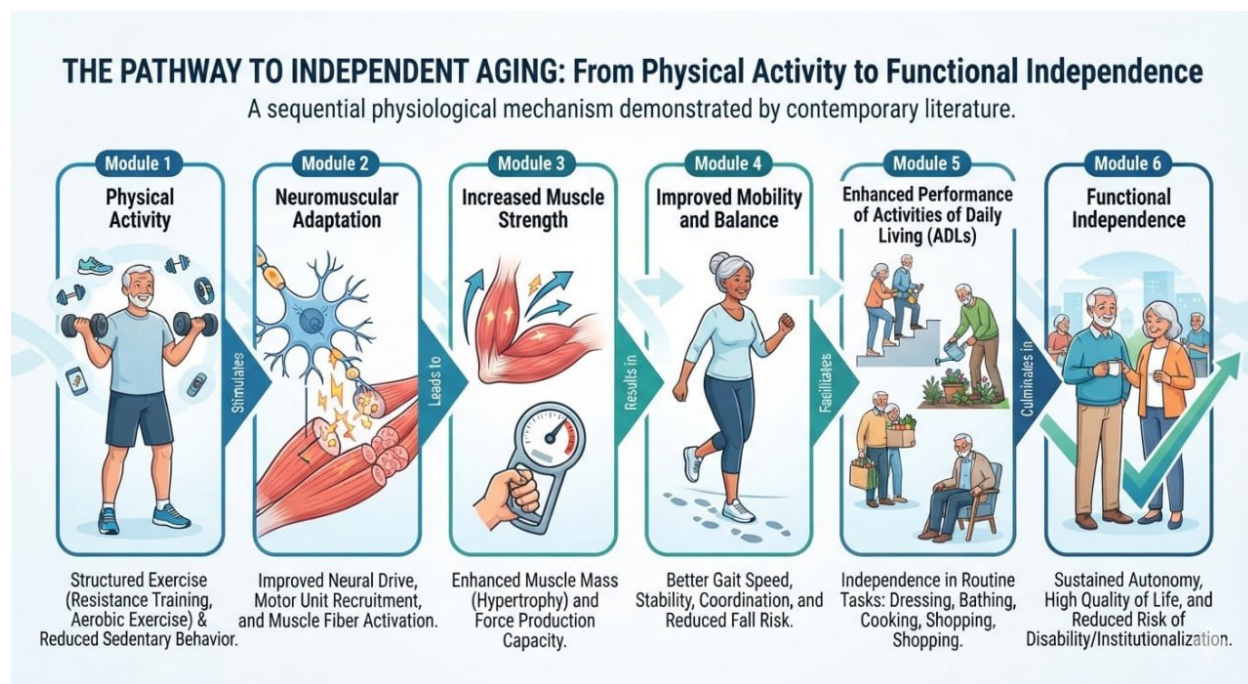


Figure 1. Proposed sequential pathway from physical activity to functional independence in older adults

This model is supported by evidence demonstrating that physical activity stimulates adaptations at multiple levels of biological organization. Exercise promotes protein synthesis, improves mitochondrial function, enhances motor unit recruitment, reduces inflammation, and preserves neuromuscular integrity [13,14,15]. These mechanisms collectively improve force production and physical performance.

Higher muscular strength subsequently facilitates locomotion, balance control, fall prevention, and successful performance of activities of daily living. As a result, individuals maintain greater autonomy and experience lower risks of disability and institutionalization.

The consistency of findings across experimental and observational studies supports the biological plausibility of this pathway and provides a conceptual framework for future intervention development.

Discussion

The present review provides comprehensive evidence supporting a strong and clinically meaningful relationship between muscle strength, physical activity level, and functional independence among older adults. The findings synthesized from recent systematic reviews, meta-analyses, randomized controlled trials, and observational studies consistently demonstrate that muscle strength represents one of the most important physiological determinants of successful aging. Furthermore, the available literature suggests that physical activity exerts substantial beneficial effects on functional independence largely through its influence on muscular performance, mobility, and neuromuscular adaptation [1,2,4,7,15].

The concept of healthy aging has evolved considerably over the past two decades. Traditionally, aging research focused primarily on disease prevention and life expectancy. Contemporary geriatric frameworks increasingly emphasize the preservation of functional capacity and the ability to live independently despite advancing age [8,9]. Within this context, maintaining muscle strength has emerged as a central objective because muscle function directly affects virtually every aspect of daily living, including mobility, self-care, social participation, and quality of life [10,15,17].

One of the most important observations emerging from contemporary literature is that muscle strength appears to be a more powerful predictor of functional outcomes than muscle mass itself. Historically, sarcopenia was largely conceptualized as an age-related loss of skeletal muscle mass. However, research conducted during the last decade has demonstrated that declines in strength occur more rapidly than declines in muscle mass and are substantially more predictive of disability, falls, institutionalization, and mortality [10,17,23]. This distinction has important clinical implications because interventions aimed exclusively at preserving muscle mass may fail to provide meaningful functional benefits unless improvements in muscle quality, neuromuscular efficiency, and force production are also achieved.

The findings presented in this review support the growing recognition of dynapenia as a critical factor in geriatric health. Dynapenia, defined as age-

associated loss of muscle strength independent of muscle mass loss, has been repeatedly associated with reduced mobility, diminished physical performance, increased frailty, and loss of independence [17,23]. Neuromuscular adaptations associated with aging, including reductions in motor unit numbers, impaired firing frequency, and diminished neural drive, likely contribute substantially to these outcomes. Consequently, assessments focusing solely on body composition may underestimate the degree of functional impairment experienced by older individuals.

The role of handgrip strength deserves particular attention. Handgrip dynamometry has become one of the most widely utilized tools in geriatric research and clinical practice because of its simplicity, low cost, and strong prognostic value [11,12]. Numerous studies have demonstrated significant relationships between low handgrip strength and increased risks of disability, hospitalization, cardiovascular disease, and mortality [11,12]. Nevertheless, while handgrip strength serves as an excellent screening indicator, lower-extremity strength may be even more relevant to functional independence because locomotion and transfer activities are predominantly dependent upon lower-body musculature. The reviewed evidence consistently shows that quadriceps strength, chair-rise performance, and lower-limb muscle power exhibit particularly strong associations with mobility and activities of daily living [1,23,25].

The present review also highlights the critical role of physical activity as a modifiable determinant of healthy aging. Although biological aging cannot be prevented, the rate and magnitude of physical decline appear highly responsive to lifestyle behaviors [15,19]. Physically active older adults consistently demonstrate superior muscular fitness, greater mobility, better balance, enhanced cardiovascular health, and lower disability rates than sedentary individuals [4,7,15]. Importantly, these benefits appear across a wide range of populations, including community-dwelling older adults, institutionalized residents, frail individuals, and adults with multiple chronic conditions [1,4].

One notable finding is the apparent dose-response relationship between physical activity and functional outcomes. Individuals engaging in higher levels of physical activity generally exhibit better physical performance and lower risk of dependency [8,19]. However, evidence also indicates that even modest increases in activity levels among previously sedentary individuals can generate meaningful improvements in functional capacity [4,20]. This observation carries significant public health implications because it suggests that substantial benefits may be achieved through relatively achievable behavioral changes.

Among the various forms of physical activity, resistance training appears particularly effective. The superiority of resistance exercise likely reflects its direct impact on neuromuscular systems responsible for force generation and functional movement [2,3,6,13]. Several meta-analyses included in this review reported significant improvements in muscle strength, gait speed, balance performance, stair climbing ability, sit-to-stand performance, and overall physical functioning following resistance training interventions [2,3,6]. These outcomes are especially important because they represent key determinants of independent living.

The effectiveness of resistance training can be explained by multiple physiological adaptations. Regular resistance exercise stimulates muscle protein synthesis through activation of anabolic signaling pathways, including the mechanistic target of rapamycin (mTOR) pathway. Resistance training also enhances motor unit recruitment, improves neuromuscular coordination, increases muscle fiber cross-sectional area, and preserves fast-twitch muscle fibers that are preferentially lost during aging [13,14,21]. Collectively, these adaptations improve force production and functional performance.

Another important consideration is the relationship between muscle strength and falls. Falls remain one of the leading causes of injury-related morbidity among older adults and contribute substantially to disability and institutionalization. Reduced lower-extremity strength compromises postural control, slowing compensatory reactions and increasing vulnerability to balance disturbances [25]. Evidence reviewed in this article suggests that exercise interventions improving muscular strength simultaneously improve balance and reduce fall risk [2,4,5]. Thus, strengthening programs may contribute to independence not only by enhancing physical capacity but also by preventing injuries that initiate cycles of functional decline.

The interplay among frailty, physical activity, and muscle strength deserves special consideration. Frailty is increasingly recognized as a multidimensional syndrome characterized by reduced physiological reserve and increased vulnerability to stressors [16]. Muscle weakness constitutes one of the defining characteristics of frailty, and several studies suggest that improvements in strength may significantly reduce frailty severity [2,16]. Importantly, the relationship is bidirectional. Frailty often results in reduced physical activity participation, which further accelerates strength loss and functional decline. Exercise programs may interrupt this cycle by improving muscular function and restoring confidence in movement.

An emerging concept in contemporary gerontology is the notion of physiological reserve. Individuals with greater strength possess larger functional reserves that allow them to tolerate illness, injury, or periods of inactivity more effectively [15,16]. In contrast, older adults with limited muscular reserves often function close to their maximal capacity during routine activities. Consequently, relatively minor health events can result in substantial losses of independence. This concept may explain why muscular strength predicts future disability even among apparently healthy individuals.

The findings of this review also support the hypothesis that muscle strength acts as a mediator linking physical activity to independence. The benefits of physical activity do not arise solely from movement itself. Rather, physical activity induces physiological adaptations that enhance muscular performance and neuromuscular function. These improvements subsequently translate into enhanced mobility, balance, and capacity to perform daily activities [2,7,15]. The proposed pathway can therefore be summarized as:

Physical Activity → Neuromuscular Adaptation → Increased Muscle Strength → Improved Physical Function → Functional Independence

This conceptual framework is supported by data from both experimental and observational studies and provides a useful model for future intervention development.

From a clinical perspective, the findings of this review support routine implementation of muscle strength assessment within geriatric practice. Handgrip dynamometry, chair-stand testing, gait speed measurements, and the Short Physical Performance Battery provide valuable information regarding an individual's current functional status and future disability risk [11,12,25]. Early identification of declining strength allows healthcare professionals to implement targeted interventions before severe functional impairment develops.

At the public health level, interventions designed to promote physical activity among older adults should represent a major priority. Population aging is expected to increase the prevalence of disability and healthcare utilization worldwide. Structured exercise programs, community-based fitness initiatives, and policies promoting lifelong physical activity participation may help reduce the societal burden associated with age-related dependency [8,9,19]. Considering the relatively low cost and high safety profile of appropriately prescribed exercise interventions, such strategies may offer one of the most cost-effective approaches to healthy aging promotion.

Several limitations of the current evidence base should be acknowledged. First, substantial heterogeneity exists across studies regarding participant characteristics, exercise interventions, and outcome measures. Second, while associations between strength and independence are consistently observed, causal relationships may be influenced by additional factors such as nutrition, cognitive function, socioeconomic status, and comorbidity burden. Third, some studies rely on self-reported physical activity measures, which may introduce reporting bias. Finally, although evidence supporting resistance training is robust, optimal training frequency, intensity, and duration remain areas requiring further investigation.

Future research should focus on identifying personalized exercise prescriptions for different subgroups of older adults. Greater attention should also be directed toward the combined effects of resistance training, nutritional interventions, and behavioral strategies on long-term maintenance of independence. Additionally, longitudinal studies with extended follow-up periods are needed to clarify whether early improvements in muscular strength translate into long-term reductions in disability and institutionalization.

Overall, the evidence reviewed strongly supports the conclusion that muscle strength and physical activity are fundamental determinants of healthy aging. Preservation of muscular function appears central to maintaining independence, reducing disability risk, and enhancing quality of life among older adults. Consequently, interventions targeting muscular strength should occupy a prominent position in future clinical, rehabilitation, and public health strategies.

Table 1. Characteristics of Key Studies Included in the Review

Study	Design	Participants	Main Outcome
Miri et al., 2024 [1]	Systematic Review and Meta-analysis	5,733	Physical activity and muscle strength significantly associated with independence
Choi et al., 2024 [2]	Meta-analysis	Multiple studies	Resistance training improved grip strength, gait speed, and balance
Kirk et al., 2024 [3]	Systematic Review and Meta-analysis	614	Machine-based resistance training improved strength and functional capacity
Valenzuela et al., 2023 [4]	Network Meta-analysis	11,609	Exercise improved physical function and independence
Costa et al., 2023 [5]	Systematic Review	Older adults	Home-based exercise improved mobility and strength
Khodadad Kashi et al., 2023 [6]	Meta-analysis	1,610	Resistance training improved muscle strength and quality of life
Wickramarachchi et al., 2023 [7]	Cross-sectional Study	880	Strength strongly predicted balance and functional performance

Conclusion

The evidence synthesized in this review supports a strong and biologically plausible relationship between muscle strength, physical activity level, and functional independence in older adults. Muscle strength represents one of the strongest predictors of independent functioning, while physical activity serves as a key modifiable determinant capable of preserving and enhancing muscle performance throughout aging.

Current evidence indicates that the benefits of physical activity are largely mediated through improvements in muscular strength, mobility, and physical function. Resistance training consistently demonstrates the greatest effectiveness for enhancing strength, reducing disability risk, and maintaining autonomy in later life.

As populations continue to age globally, interventions that promote muscle-strengthening physical activity should become an essential component of clinical practice, rehabilitation programs, and public health policy aimed at supporting healthy aging and reducing age-related dependency.

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