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Commentary

Functional Resistance Training and the Kinetic Chain for Healthy Aging

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Introduction

In my previous article, "Aging With Strength: Functional Training to Support Independence and Quality of Life," I examined how Functional Resistance Training (FRT) compares to traditional strength training, providing a proactive approach to maintaining muscular strength, postural control, and autonomy for older adults. Since then, growing evidence has shifted attention beyond sarcopenia as a matter of muscle mass loss alone toward broader deficits in movement quality and neuromuscular coordination that contribute to disability. Age-related mobility decline and sarcopenia progression result not only from muscle loss but also from disruptions in the kinetic chain—the cohesive system of joints, muscles, and neural pathways responsible for producing efficient, coordinated movement [1-4]. These disruptions manifest clinically as impaired gait, balance instability, and reduced adaptive capacity during activities of daily living.

This commentary builds on that model by reframing FRT as a systems-level intervention to restore and preserve movement throughout the lifespan, thereby enhancing health-related quality of life. FRT may serve as a bridge between sarcopenia prevention and mobility preservation, ultimately supporting critical outcomes in healthy aging: independence, safety, and quality of life.

The Aging Kinetic Chain

The kinetic chain- a biomechanical system in which joints, muscles, and neural pathways operate in coordination- is crucial for understanding age-related decline in mobility. With advancing age, this kinetic chain becomes increasingly vulnerable to muscle weakness, joint stiffness, diminished proprioception, and impaired neuromuscular control [5,6]. These deficits are interrelated; for example, gluteal weakness alters pelvic alignment and knee tracking, increasing instability during walking or transfers, such as sitting to standing. Targeted interventions aimed at restoring proprioception and joint function within a single segment of the chain—such as Closed Kinetic Chain Exercises (CKCE)—have demonstrated improvements in pain, proprioceptive accuracy, and functional mobility [7]. These findings highlight the principle that improving one link in the chain can enhance overall movement quality, particularly when exercises are designed to reflect the complex, multi-joint demands of daily life. Similarly, distal chain impairments—such as weakened ankle musculature or sensory degradation—can compromise dynamic balance and elevate fall risk. Intervention studies indicate that both resistance and sensorimotor training improve lower limb strength and postural control, highlighting the importance of integrative exercises in addressing distal chain impairments that increase fall risk [8].

Degradation of the kinetic chain contributes to impaired force production and multi-joint coordination. These neuromuscular disruptions become evident in compensatory movement patterns, postural instability, and inefficient gait. As noted in recent findings, even minor impairments in balance and strength may precede the development of significant disability [9]. Traditional exercise prescriptions often emphasize isolated strength through machines or seated exercises, neglecting the integrative demands of daily movement. For example, bench pressing targets upper-body muscles but fails to replicate real-life pushing tasks that involve the core and lower body. In contrast, FRT emphasizes closed-chain, multi-joint exercises that mirror everyday activities. When implemented strategically, FRT enhances muscular power and the intersegmental coordination essential for functional independence and fall prevention [10].

Sarcopenia and Mobility—A Neuromuscular Systems-Level Challenge

Sarcopenia is a progressive disorder marked by declining muscle strength, mass, and physical performance [11,12]. Contemporary definitions, including those from the Global Leadership Initiative on Sarcopenia, now prioritize muscle strength over mass as a predictor of adverse outcomes [1]. Emerging evidence suggests that sarcopenia encompasses neuromuscular impairments, characterized by reduced force generation capacity, recruitment inefficiencies, and joint instability [11]. These deficits are not adequately addressed by hypertrophy-focused training [13]. Although resistance exercise is recommended, conventional prescriptions focus mainly on hypertrophy; older adults with sarcopenia may not fully experience functional benefits [12]. Emerging modalities, including High-Intensity Functional Training (HIFT), have demonstrated significant benefits in improving strength, power, speed, and agility—characteristics closely tied to neuromuscular function—although current evidence is primarily drawn from healthy populations [14]. Integrating such functional approaches may more effectively address the complex neuromuscular deficits inherent in sarcopenia and promote enhanced physical performance.

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Mobility loss remains central to sarcopenia's impact, reducing independence and increasing fall risk in aging adults. Interventions that enhance functional performance, especially lower limb power and dynamic movement, are crucial for preserving mobility. FRT and HIFT have shown promise in improving performance variables such as sprinting, jumping, and task-specific mobility [15]. While most FRT data are derived from younger cohorts, early evidence suggests that HIFT is both feasible and potentially effective for improving physical function and daily activity engagement in older adults [16]. These findings highlight the need for interventions that extend beyond muscle mass to target neuromuscular output and movement efficiency.

Machine-based, open-chain exercises improve isolated strength but do little to restore balance, proprioception, and coordination—factors essential for preventing falls and maintaining autonomy [7]. In contrast, FRT incorporates closed-chain, compound movements that activate the entire kinetic chain and better simulate real-world demands [17]. Resistance training not only preserves and enhances muscular strength but also appears to induce significant neurobiological adaptations, including functional brain changes predominantly in the frontal lobe, which correlate with improved executive function and potentially slower white matter atrophy—effects that may be particularly beneficial for older adults experiencing sarcopenia and cognitive decline [18]. To address sarcopenia systemically, clinicians should emphasize multimodal interventions that integrate strength, balance, and neuromuscular control. When combined with neuromotor training, FRT offers a targeted approach to reducing disability and maintaining functional independence. Clinical implementation must be individualized, taking into account comorbidities, motor learning capacity and the stage of rehabilitation.

Restoring Neuromuscular Function in Aging Adults Through FRT

FRT is a clinically viable modality for restoring kinetic chain integrity in aging adults, effectively addressing sarcopenia, neuromuscular inefficiency, and postural dysfunction. Unlike traditional resistance protocols that isolate muscle groups, FRT utilizes compound, closed-chain movements that replicate functional tasks, improving coordination, proprioception, and postural control. Exercises such as squats, lunges, and step-ups enhance joint stabilization and sensorimotor feedback, which are critical for kinetic-chain synchronization and reducing compensatory patterns [19,20].

Emerging evidence suggests that closed-chain modalities are superior to open-chain approaches in promoting upper-body power and force transfer [21]. Additionally, proprioceptive training models have improved movement accuracy by 46% and motor performance by 45% across diverse populations [22], suggesting enhanced neuromuscular efficiency. Integrative FRT elicits these benefits through multi-planar movements that reinforce functional biomechanics and mitigate age-related decline. Upper-body FRT contributes to proximal stability and postural restoration via exercises such as standing rows, resisted push–pulls, and medicine ball throws. Resistance band training has been shown to improve scapular positioning and shoulder alignment in older adults [23,24]. These strategies address kyphosis and forward head posture—common deficits that impair reaching, lifting, and balance—while enhancing kinetic-chain force transmission and potentially reducing fall risk [2,25].

Neurologically, FRT improves motor unit recruitment, cortical activation, and dynamic stability—parameters that deteriorate with age and compromise movement quality [26]. High-velocity concentric tasks, such as power-based chair stands, promote rapid force development, which is essential for reactive balance [27]. Furthermore, resistance training has been shown to have cognitive benefits, including enhanced memory, executive function, and cortical plasticity in aging populations [28].

Beyond Muscle: Functional Resistance Training for Public Health and Aging

Combating sarcopenia and mobility loss requires adaptable, patient-centered interventions. FRT stands out for its flexibility, affordability, and ability to simultaneously target strength, balance, and coordination—core components of geriatric care—as supported by emerging research in lower-resource settings [29]. Clinicians, such as physical and occupational therapists, geriatricians, and exercise physiologists, can apply FRT in both prevention and rehabilitation, aligning with best practices for fall prevention and mobility restoration. Multicomponent programs combining resistance, balance, and aerobic elements have been shown to result in significant gains in walking speed, limb strength, and aerobic capacity [30-32]. Meta-analytic comparisons—including those evaluating functional exercise programs—suggest these interventions outperform resistance training alone in improving balance and mobility outcomes [30-33]. FRT's flexibility allows tailoring to individual strength levels, cognitive status, and comorbidities, promoting equitable, personalized care.

Nonetheless, implementation challenges persist. Many fitness professionals lack formal training in gerontology, and healthcare providers may underappreciate the role of exercise specialists due to limited awareness of their qualifications. Primary care clinicians and physiotherapists often receive minimal education in exercise prescription and report low rates of resistance training use among older adults, citing unclear guidelines, competing priorities, and perceived patient limitations [34]. Structural barriers—including transportation, socioeconomic factors, and racial disparities—further restrict access to adequate and safe exercise programming [35,36].

Addressing these challenges requires interdisciplinary collaboration and policy reform. Medicare reimbursement for preventive programs, continuing education for providers, and public-private partnerships may help expand access and improve care delivery. Still, several key questions remain unanswered and should guide future research and implementation efforts:

- How effective is FRT in enhancing long-term functional independence among older adults with cognitive or sensory impairments?
- What are the most scalable and cost-effective models for delivering FRT in low-resource and underserved settings?
- How can interdisciplinary education be improved to ensure clinicians and fitness professionals are adequately trained to prescribe FRT?
- Which components of multicomponent training (e.g., resistance, balance, aerobic) drive the most significant gains in mobility and fall prevention, and how can these be optimized?

- What policy mechanisms could facilitate broader adoption, such as insurance reimbursement, community partnerships, or standardized clinical guidelines?

Addressing these questions will be essential to ensuring that FRT reaches its full potential as an equitable, evidence-based cornerstone of aging care.

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