Annals of Gerontology and Geriatrics

Article Type: Review Article

Volume 1

Exercise in disguise: Reversing and preventing frailty with CAMMO

Mike Studer, PT, DPT, MHS, NCS, CEEAA, CWT, CSST, CBFP, CSRP, FAPTA*

Physical Therapy, Touro University, Henderson, Nevada, USA.
PTI, University of Nevada Las Vegas 89154, USA.

***Corresponding author: Mike Studer**,
Physical Therapy, Touro University, Henderson, Nevada, USA.
Email: mike@mikestuder.com

Received: May 10, 2025; **Accepted:** May 28, 2025; **Published:** Jun 04, 2025

Annals of Gerontology and Geriatrics
www.annggr.org

Citation: Studer M. Exercise in disguise: Reversing and preventing frailty with CAMMO. Ann Gerontol Geriatr Res. 2025; 1(1): 1005.

Abstract

With the aging of populations across the world combined with advances leading to extended lifespan, the incidence of frailty is on the rise. In the United States there are just over 60 million individuals over 65 years old at this time. Research estimates the incidence of frailty in persons over 65 to be between 21 and 33%. Research estimates the elevated cost per year of a person with frailty to range from $2500 to $12000 USD, depending on the number of frailty phenotypes present in the individual. Calculations indicate that frailty in the United States will cost between 30 billion and 140 billion per year. While there is an increasing consensus about how to define frailty, current strategies for intervention have not proven successful in preventing or reversing frailty. In this call-to-action perspective article, we present a novel strategy intended to influence current practice and future research in frailty. This strategy is differentiated from contemporary practice in that it leverages advances in: personalized medicine, behavioral economics, and the differences between "physical activity" and "exercise" in an effort to create a novel method intended to both prevent and mitigate frailty. This novel method is intended to be more effective through greater adoption and consistency, resulting in reduced physical frailty and the downstream consequences of healthcare costs, falls, death rates and nursing home admission.

Keywords: Sarcopenia; Frailty; Isometric; Physical activity; Rehabilitation.

Introduction

Many aspects of medicine and rehabilitation have recently adopted the forward-thinking terms "precision medicine" or "precision rehabilitation". This contemporary term evokes the notion that care is delivered at the right dose, at the right time, to the right person. It is in this vein that CAMMO – Contract Accelerate Micro Move Often – both describes and offers practical, evidence-based, multifocal, yet previously invisible opportunities for physical activity to reverse or prevent frailty. This approach is meant to be approachable, and intuitive, providing Persons with Frailty (PwF) with a tool that is easy to remember and can be applied frequently. While it is likely evident that the title of this article was chosen to feel playful and obvious, "CAMMO" and "invisible". The term exercise was employed to be evident for a layperson population (many people understand the term) and…because it rhymes with the inherent theme of invisibility (CAMMO), "exercise in disguise", with the goal of increasing patient engagement. It should be noted that physical activity would be the best medical term going forward and more accurately describes the full range of movement opportunities.

Contemporary interventions to prevent or reverse frailty have demonstrated mixed success. Treacy and colleagues (2022) performed a systematic review that included 12 RCTs, with 1317 participants, carried out in 9 countries. The median number of participants across the trials was 97, amassing over 1300 subjects with a mean age of the included participants being 82 years old. The authors' work revealed some significant findings as they wrote, "High-certainty evidence shows that compared to control, mobility training improves the level of mobility, and moderate-certainty evidence shows it may improve the level of

functioning in frail community-dwelling older people. There is moderate-certainty evidence that the improvement in mobility continues for six months post-intervention. Mobility training may make little to no difference to the number of people who fall or are admitted to nursing care facilities, or to the death rate [1]. ”

The incidence and costs of frailty

According to the National Council on Aging (NCOA), there were 57.8 million adults age 65+ living in the U.S. in 2022. This included 31.9 million women and 25.9 million men [2]. When these figures are coupled with the incidence of frailty estimates by Treacy (21% incidence for persons over 65 in the United States) and Veronese (25-33%), this yields a conservative estimate of 13 million frail adults in the US in 2025. This figure could reasonably be estimated on the high end to be 16 million [3].

Ensrud and colleagues (2023) studied the claims data for persons with frailty in the United States. This group wrote, “During the 36 months following the index examination, mean (SD) annualized costs were $13906 (24499) for women and $14598 (28556) for men.” The authors note that costs were incrementally higher in each person when more phenotypes of frailty were present, and when functional impairments were considered. This range included, “Average incremental costs ranged from $2093 to $9627 among men with vs. men without functional impairments.”. In conclusion, the authors noted that PwF with up to four phenotypes of frailty could expect to consume from $8124 (women) to $11831 (men) in those without impairments and up to $18792 among frail women and $24713 among frail men with four phenotypes including functional impairments.

Using the conservative estimate of 13 million and the data on costs from Ensrud and colleagues (2023), we see that in 2023, PwF could be expected to consume a low-estimate of $30 billion USD in healthcare expenses per year (at 2500 per PwF/year) or as much as 145 billion (12000 per PwF/year).

Extrapolating statistics to include the rate at which the US population is aging, Aubertin-Leheudre and colleagues estimated that there would be 89 million people over 65 years old i n the United States by 2050 [4]. Applying the aforementioned ranges for the incidence of frailty and costs in today’s dollars, it would be reasonable to estimate that in just 25 years frailty would be expected to burden the US economy in the range of 55 billion to 267 billion per year.

Defining frailty

In general, a nearly-consensus definition of frailty includes a syndrome of reduced physiological reserve and impaired response to stressors [5]. More specifically, frailty is defined by the presence of clinical indicators and is classified by physical phenotypes detailed below, using one of several approaches that are all largely in agreement. While some authors additionally identify frailty across pillars of physical function, cognitive function, social connectedness/support and oral health, this article will remain focused on physical frailty. Noteworthy and related, each of these classifications of frailty are predictive for having another form, the strongest being social frailty’s predictability for having both cognitive and physical frailty.

Most of the frailty research is conducted on physical frailty, which serves as an independent predictor of poor recovery from disability among nondisabled older adults. In some cases, frailty comes on rapidly or “strikes” after illness or injury. In most cases, frailty is acquired through chronic illness in combination with inactivity [6-10]. McDermid et al., 2011 noted that critically ill patients of all ages may share characteristics with frail elderly patients. A common physiology can be found in inflammaging. As the authors write, “deficits associated with frailty, which typically take years to accumulate in the outpatient geriatric population, rapidly develop in a large proportion of critically ill patients independent of age and illness severity”, they continue in the same paper to add, “One hypothesis whereby ageing is associated with and may predispose to development of frailty relates to the concept of inflammaging: the dynamic interplay between the protective proinflammatory response to invading microorganisms and the similarly protective compensatory anti-inflammatory system, which defends against uncontrolled inflammation [11]”.

In their 2006 study, Gill and colleagues defined prefrailty as having 1 or 2 of the following criteria, and frailty as having 3 of or more of the following criteria: weight loss, exhaustion, low physical activity, muscle weakness, or slow walking speed. In their longitudinal study of 754 individuals aged 70 years and older, the group observed movement in and out of frailty over 36 months [12]. It is worth noting that Gil and colleagues found movement toward greater levels of frailty (e.g. prefrail to frail) to be nearly two times more common than four persons to experience a resolution of frailty (e.g. prefrail to not frail/no frailty indicators).

Wu and colleagues (2018) studied frailty across 1054 subjects. They defined frailty in a similar manner, writing, “Frailty was assessed by slowness, weakness, exhaustion, inactivity, and shrinking. Persons were classified as “nonfrail” (0 criteria), “prefrail” (1–2 criteria), or “frail” (3–5 criteria) [13].”

In one of the most frequently cited and seminal studies on frailty, Fried et al., 2001 defined frailty as, “…a biological syndrome with specific phenotypic presentations and defines frailty as having three or more of five physical components: unintentional weight loss, self-reported exhaustion, weakness, slow walking speed and low physical activity”

There is increasing agreement around the specific parameters in each phenotype. Unintentional weight loss is largely agreed to be 10 pounds or more, weakness is most often identified by grip strength, and slow walking speed is often cited as walking slower than 1 meter/second.

When frailty as defined by Fried is present (3 or more of the above stated criteria are met), it can predict death rates, nursing home admission, disability, unintentional solitude/loneliness, falls, fractures, hospitalization, hospital length of stay, lower quality of life, cognitive decline, dementia, and depression [14-19].

Outside of phenotyping through Fried’s model, frailty can be defined by the Comprehensive Geriatric Assessment (CGA), which is largely considered to be the gold standard; the Edmonton Frail Scale (Wyrko, 2015), Frailty Index (Mitnitski 2001), the Frail Scale (Woo 2012) and the Clinical Frailty Scale (CFS) (Rockwood, 2005) [20,21]. Additionally, single tests can identify frailty phenotypes including grip strength, slow walking speed (>5 seconds to walk 4 meters); the Timed up-and-go test (>10 seconds by some and as high as 14 seconds by other citations); or a score of 3 or above on the PRISMA 7 questionnaire [22].

Contemporary approaches to prevent and reverse frailty

Treacy and colleagues Performed a systematic review including over 1300 subjects averaging 82 years old, across 12 separate studies. Their findings, published in 2022, represented a comprehensive representation of mobility interventions for frailty at the time of publication. While mobility training was found to be effective in improving function and improving mobility-based impairment scores. However, the interventions did not have a significant effect on nursing home admission rates, fall frequency, or death rates. While there are many phenotypes of frailty, a common experience is physical frailty. Why then would improving mobility (function or impairment) not have an impact on the downstream effects of frailty (death, falls, nursing home admission)?.

Across their above-referenced systematic review, Treacy and colleagues noted several common interventions used to increase mobility. These interventions included: whole task-specific mobility training (sit to stand, walking); part-task of the same; as well as balance-challenging exercises.

In their 2023 article entitled, "Exercise to Prevent and Manage Frailty and Fragility Fractures", Dent and colleagues provided an overview of the evidence and clinical practice guidelines available regarding the benefits of exercise for the prevention and recovery from frailty. In their conclusory remarks, the authors voice a call to action that is seemingly answered point-point by the CAMMO approach. Dent writes,"… (CPGs and evidence in frailty) These findings can be used by policy makers, healthcare professionals, and consumers to inform decision making regarding exercise for older adults with or at increased risk of frailty… We need to do more of what works and explore how to best implement evidence-based program into real world settings. There is sufficient evidence, supported by clinical practice guidelines, that we need to focus attention on implementing exercise interventions given their proven effectiveness for multiple musculoskeletal health outcomes. For optimal benefits, exercise programs need to be personalised based on each person's medical history, health status, preferences, and priorities. Future research should focus on how to cost-effectively implement exercise interventions into daily life, including how to increase uptake and adherence to such programs."

As you will read, the CAMMO approach, intends to be personalized, effective, evidence-based, considerate of present fitness and health status, and implementable within a person's daily life. We will read about each of these, as related to CAMMO, in the sections that follow.

CAMMO: Contract

A person that has frailty (Person with Frailty or PwF) or one that is at risk for frailty could make even a bedridden effort to contract each of their major muscle groups - without moving. Many people know this as isometric contractions, a term and approach that had fallen out of favor for some time but has now made a resurgence. Isometrics are now utilized more frequently to build tissue hygiene (appropriate for PwF), to improve neuromuscular re-education/recruitment, and to provide a reasonable entry point with consideration of persistent pain [23-30]. Contracting your muscles without moving can be done by pushing down into a bed pushing down into the floor or even muscles holding position and working against each other. Many patients identify with the term "flexing" more readily than they might with the explanation of contracting without moving. As a provider, be certain to have some fun with this and give your patient the opportunity to, "Act like you are a bodybuilder and just hold position in a 'pose'". For the right person and situation, this could resonate well. Understanding that there is no one-size fits all intervention for preventing or reversing severe frailty, "contract" is but one strategy in a multimodal approach.

CAMMO: Accelerate

Persons with frailty that are not bedridden but are frail or at risk for it need easy opportunities to reverse their condition. These daily life opportunities to accelerate may seem counter-intuitive to the experience of frailty, yet this does not need to be the case. Based in the literature on Vigorous Intermittent Lifestyle Physical Activity (VILPA), we see that everyday movements played at "2X speed" would be an example of accelerate. This may include something as small as rolling over in bed, or as large as an accelerated sit to stand from a high (easy) surface. If a PwF is only capable of moving from lying down to sitting up, they may try to do two full repetitions of this very safe and controlled movement - as fast as they can. The dosage can be this simple. For those with a piece of stationary exercise equipment at home, accelerate becomes tangible (and measurable) by picking up the pedaling rate on an elliptical stepper or bike of any kind.

Creating more force than what is necessary for a movement can steadily rebuild force capacities. When a PwF moves from sitting to standing, a provider or caregiver might encourage them to "try to do it fast one time". If this person is ambulatory with assistance, they might "pick up the pace" for even just a couple of steps. Recall that VILPA is person and condition-specific. Moving just beyond your daily life speed is a stimulus, even if it means advancing from .2 m/s to .3 m/s on level ground gait. The psychologic benefits of accelerate are not insignificant, as this approach provides PwF with frictionless access to movement that is in the context of life, giving clear translatability to the task at hand. When a health or wellness benefit can be gained without costing extra time, we may recognize an additional psychologic benefit, known as habit stacking – which will be described in detail below.

While it may be evident that the physiologic benefits of accelerate can be found in neuromuscular recruitment, energy production, and cardiovascular demands, there may be more to the story. Accelerate is related in kind to the now well-established approach of Vigorous Intermittent Lifestyle Physical Activity (VILPA), popularized by Stamatakis in many publications. To be clear, VILPA is yet to be studied formally in persons with frailty, however the physiologic bases is established and the mechanisms are increasingly more clear. Stamatakis and colleagues (in a 2024 article led by Pang) describe the physiologic bases for VILPA as follows, "Vigorous Intermittent Lifestyle Physical Activity (VILPA) are bursts of incidental vigorous activity that occur during day-to-day activities outside of the exercise-domain.", the group continued on, detailing some of the recent advances in VILPA, adding, "…large population based studies have shown 4 min of VILPA per day is associated with 25% to 50% lower disease and mortality risk… [31,32]".

Stamatakis and colleagues continued to make their case for VILPA in their 2024 article, with the lead author Pang. This work serves as a part of the evidence for accelerate, notably in the population of PwF, as they write, "Correspondingly, the MET intensity of any given activity is higher in older and physically inactive adults who are highly sedentary…physically inactive

middle-aged and older adults are engaging in VILPA through their everyday activities and may not be aware of it.".

CAMMO: Micro move (MM)

"Micro Move" is a fun and approachable addition to the concept of CAMMO. While seated at a table, the action of just fidgeting your legs or lifting your heels up by raising up on toes are the most intuitive examples of micro moves. These activities can help to stimulate our energy systems and stave off frailty as compared to no motion at all. Other examples of micro moves can include sliding your feet back and forth either when lying in bed or sitting, small snow Angels in bed pumping your feet (often known as ankle pumps) and many more.

The physiology of micro moves is grounded in established concepts such as Non Exercise Activity Thermogenesis (NEAT) [33], in the re-establishment of mitochondrial biogenesis, in angiogenesis, and in rebuilding muscle for greater insulin sensitivity [34].

Perhaps more importantly, the *psychology* of micro moves may be even more powerful. Micro moves can feel reachable, approachable, like "exercise snacks". Exercise snacks define the capacity to "reach over and grab a handful of health". These bite sized packages of movement have been elevated in popularity across the behavioral economics (nudge) and physical activity literature over the past 5 years [35].

Finally, and perhaps most salient for the intensity of accelerate and supporting the brevity of micro move, Stamatakis, Pang and colleagues write in their 2024 article, "Currently, the length of incidental high-intensity activity prescribed in trials can vary from short bursts lasting a few seconds..."

CAMMO: Often

Here's where the CAMMO concept has a unique opportunity. Rather than disengaging or "scaring people off" with a scientific prescription, the "O" in CAMMO, is "often". This provides space for an individual to begin where they are and where they can, without the burden of recommended guidelines or normative data. Starting any new habit, especially from a condition of frailty, needs to feel easy. Healthcare providers, caregivers, and PwF can define "often" as they please, and continue to re-define it as they progress. Allow PwF to control something in their lives - let them choose how often an initial dosage feels reasonable. While news headlines remind us how few adults are meeting worldwide physical activity guidelines (World Health Organization, Centers for Disease Control, American College of Sports Medicine), it can give one the impression that these minimum standards are out of reach – "and always will be…so why bother trying?". The intent of "often" is positioned with this "seemingly out of reach" mentality in mind, by empowering frail individuals, with choice.

This concept of choice (PwF encouraged to procure bite-sized exercise snacks frequently, yet ultimately leaving the decision of frequency up to the user) represents the evidence of autonomy, self-efficacy, and the placebo effect. All three will be addressed in greater detail below. As many readers will attest, the traits of autonomy, self-efficacy and belief (the added power of a placebo-effect directed at an intervention with scientific merit), are three traits that we would love to have (or foster) in any person that we have the opportunity to serve, for any condition.

Measuring frailty

While there are many means by which to measure frailty, it is seemingly less important to capture frailty with technology, than it is to ensure that it is objectified – somehow. As first described by Fried and colleagues, frailty has many phenotypes. As such, frailty can be measured using many instruments – be those with technology or examination tools. Measurement may be important for research, for program marketing, for reimbursement, for visit advocacy, or even for state regulations. However, it could be argued that the most important reason to objectify a baseline and continue to track progression, would be for the benefits to the PwF.

Providers may employ technology including body-worn accelerometers to capture patient activity (steps, turns, distance traveled, "trips" or frequency of locomotion, or even total upright time) [36,37].

Alternatively, Patient Reported Outcome Measures (PROMs) can be used to identify baseline and progress in activity.

Finally, examination tools can be employed to demonstrate the reversal of frailty. These can include a battery of measures, the most common being the Short Performance Physical Battery (SPPB). Alternatively, frailty can be defined in singular measures of capacity (e.g. 10 meter walk, 5 times sit to stand), measures of fatigability (e.g. 30 second sit to stand, 2 minute walk test) or measures of performance (community access, steps per day).

Why CAMMO – the scientific difference

Frailty is a syndrome and not a singular disease. As such, it may receive less attention in research, organization, press and endowments/organizations to address education and prevention. As noted above, the prevalence of frailty rivals and exceeds that of Alzheimer's Disease and Parkinson's Disease combined, noting some overlap in that some persons with each of these degenerative diseases, are at higher risk to become frail.

While most of the research to date has attempted to resolve physical frailty, Dent and colleagues reported as recently as 2023 that much more needed to be done to establish a clinical pathway for prevention or resolution. Anecdotally, readers may have experiences within health care that assume frailty can be mitigated but never reversed.

It is for this reason that CAMMO needed to be something different. An approach that felt convenient for individuals with such low energy that leaving the home for an appointment might leave them without enough reserve to participate. CAMMO is differentiated in the following ways:

1. Repurposing daily physical activity
2. Increasing the value (appropriately supported in literature) of isometric contractions
3. Providing autonomy for frequency in the form of often, without burdening PwF with a lofty standard

As stated in this paper, CAMMO is a different approach to frailty than what we have seen in past practice or research. This multimodal approach has a basis in behavioral economics (nudge, gamification, exercise snack, habit stacking); a basis in psychology (autonomy, self-efficacy, belief/placebo effect); and basis in physiology (NEAT, VILPA, isometrics, intensity and the training principle of consistency).

The potential benefits of CAMMO deserve to be studied in a concentrated manner, ideally within a homologous group of PwF with a uniform physical frailty phenotype. Possibilities include a promotion of mitochondrial biogenesis, leveraging the reward system (largely dopamine-based), the possible mobilization of lactate and downstream Brain Derived Neurotrophic Factor (BDNF) as well as Growth Hormone (GH). It is not unreasonable to expect mental health improvements to stem secondarily from these physiologic processes and the sheer benefit of seeing progress.

Conclusion

Statistics are informing us that the incidence of frailty is outpacing societal aging. Our current efforts to prevent and reverse Frailty have not demonstrated effectiveness. Individuals with frailty can experience concomitant mental health impairments, have low self-efficacy, and/or report low energy reserves. One of these three could be in to keep an individual from consistently participating in an efficacious program to combat frailty. We may not need new evidence or new interventions, but rather a new approach. Providing an approach that includes several different forms of physical activity that can all be inserted with daily movements and are geographically slash temporally available (exercise snacks), CAMMO may be that novel approach. Research using this approach will be revealing and should be forthcoming.

References

1. Treacy D, Hassett L, Schurr K, Fairhall NJ, Cameron ID, Sherrington C. Mobility training for increasing mobility and functioning in older people with frailty. Cochrane Database Syst Rev. 2022; 6: CD010494.
2. Get the facts on older Americans. (n.d.). The National Council on Aging (NCOA). 2025. from https://www.ncoa.org/article/get-the-facts-on-older-americans/
3. Veronese N, Custodero C, Cella A, et al. Prevalence of multidimensional frailty and pre-frailty in older people in different settings: A systematic review and meta-analysis. Ageing Res Rev. 2021; 72: 101498.
4. Aubertin-Leheudre M, Woods AJ, Anton S, Cohen R, Pahor M. Frailty Clinical Phenotype: A Physical and Cognitive Point of View. Nestle Nutr Inst Workshop Ser. 2015; 83: 55-63.
5. Mishra S, Premkumar M. Nutritional Management of a Liver Transplant Candidate. J Clin Exp Hepatol. 2023; 13: 878-894.
6. Panza F, Lozupone M, Dibello V. Multidimensional complex frailty phenotypes: epidemiological impact of oral frailty in older age. Eur Geriatr Med. 2024; 15: 505-507.
7. Tsutsumimoto K, Doi T, Makizako H, et al. Association of Social Frailty with Both Cognitive and Physical Deficits Among Older People. J Am Med Dir Assoc. 2017; 18: 603-607.
8. Fried LP, Tangen CM, Walston J, et al. Frailty in older adults: evidence for a phenotype. J Gerontol A Biol Sci Med Sci. 2001; 56: M146-M156.
9. Mitnitski AB, Mogilner AJ, Rockwood K. Accumulation of deficits as a proxy measure of aging. The Scientific World Journal. 2001; 1: 323-336.
10. Tsutsumimoto K, Doi T, Makizako H, et al. Association of Social Frailty with Both Cognitive and Physical Deficits Among Older People. J Am Med Dir Assoc. 2017; 18: 603-607.
11. McDermid RC, Stelfox HT, Bagshaw SM. Frailty in the critically ill: a novel concept. Crit Care. 2011; 15: 301.
12. Gill TM, Gahbauer EA, Allore HG, Han L. Transitions between frailty states among community-living older persons. Arch Intern Med. 2006; 166: 418-423.
13. Wu C, Kim DH, Xue QL, Lee DSH, Varadhan R, Odden MC. Association of Frailty with Recovery from Disability Among Community-Dwelling Older Adults: Results From Two Large U.S. Cohorts. J Gerontol A Biol Sci Med Sci. 2019; 74: 575-581.
14. Ensrud KE, Ewing SK, Taylor BC, Fink HA, Stone KL, Cauley JA, et al. Frailty and risk of falls, fracture, and mortality in older women: the study of osteoporotic fractures. J Gerontol A Biol Sci Med Sci. 2007; 62: 744–51.
15. Kojima G, Iliffe S, Jivraj S, Walters K. Association between frailty and quality of life among community-dwelling older people: a systematic review and meta-analysis. J Epidemiol Community Health. 2016; 70: 716–21.
16. Soysal P, Veronese N, Thompson T, Kahl KG, Fernandes BS, Prina AM, et al. Relationship between depression and frailty in older adults: a systematic review and meta-analysis. Ageing Res Rev. 2017; 36: 78–87.
17. Kojima G, Taniguchi Y, Iliffe S, Walters K. Frailty as a predictor of alzheimer disease, vascular dementia, and all dementia among community-dwelling older people: a systematic review and meta-analysis. J Am Med Dir Assoc. 2016; 17: 881–8.
18. Robertson DA, Savva GM, Kenny RA. Frailty and cognitive impairment—a review of the evidence and causal mechanisms. Ageing Res Rev. 2013; 12: 840–51.
19. Kojima G. Frailty as a predictor of nursing home placement among community-dwelling older adults: a systematic review and meta-analysis. J Geriatr Phys Ther. 2018; 41: 42–8.
20. Mitnitski AB, Song X, Rockwood K. The estimation of relative fitness and frailty in community-dwelling older adults using self-report data. J Gerontol A Biol Sci Med Sci. 2004; 59: M627-M632.
21. Woo J, Leung J, Morley JE. Comparison of frailty indicators based on clinical phenotype and the multiple deficit approach in predicting mortality and physical limitation. J Am Geriatr Soc. 2012; 60: 1478-1486.
22. Woolford SJ, Sohan O, Dennison EM, Cooper C, Patel HP. Approaches to the diagnosis and prevention of frailty. Aging Clin Exp Res. 2020; 32: 1629-1637.
23. Ji F, Lee HS, Lee H, Kim JH. The impact of frailty syndrome on skeletal muscle histology: preventive effects of exercise. FEBS Open Bio. 2025. doi:10.1002/2211-5463.70049
24. Angulo J, El Assar M, Álvarez-Bustos A, Rodríguez-Mañas L. Physical activity and exercise: Strategies to manage frailty. Redox Biol. 2020; 35: 101513.
25. Nascimento CM, Ingles M, Salvador-Pascual A, Cominetti MR, Gomez-Cabrera MC, Viña J. Sarcopenia, frailty and their prevention by exercise. Free Radic Biol Med. 2019; 132: 42-49.
26. Harding AT, Weeks BK, Lambert C, Watson SL, Weis LJ, Beck BR. Effects of supervised high-intensity resistance and impact training or machine-based isometric training on regional bone geometry and strength in middle-aged and older men with low bone mass: The LIFTMOR-M semi-randomised controlled trial. Bone. 2020; 136: 115362.

27. Iyota K, Mizutani S, Kishimoto H, et al. Effect of Isometric Tongue Lifting Exercise on Oral Function, Physical Function, and Body Composition in Community-Dwelling Older Individuals: A Pilot Study. Gerontology. 2022; 68: 644-654.

28. Varadhan R, Russ DW, Gabr RE, et al. Relationship of Physical Frailty to Phosphocreatine Recovery in Muscle after Mild Exercise Stress in the Oldest-Old Women. J Frailty Aging. 2019; 8: 162-168.

29. Rio E, Kidgell D, Purdam C, et al. Isometric exercise induces analgesia and reduces inhibition in patellar tendinopathy. Br J Sports Med. 2015; 49: 1277-1283.

30. Alarab A, Shameh RA, Ahmad MS. Muscle contraction exercise for low back pain. Hong Kong Physiother J. 2023; 43: 53-60.

31. Pang B, Moullin JC, Thompson C, Thøgersen-Ntoumani C, Stamatakis E, McVeigh JA. Barriers and Facilitators to Participation in Vigorous Lifestyle Physical Activity in Adults Aged 55-75 Years: A Scoping Review. J Aging Phys Act. 2024; 32: 446-459.

32. Ahmadi MN, Holtermann A, Tudor-Locke C, et al. Time to Elicit Physiological and Exertional Vigorous Responses from Daily Living Activities: Setting Foundations of an Empirical Definition of VILPA. Med Sci Sports Exerc. 2024; 56: 2413-2420.

33. Correia IR, Hetherington-Rauth M, Magalhães JP, et al. Compensatory mechanisms from different exercise intensities in type 2 diabetes: a secondary analysis of a 1-year randomized controlled trial. Acta Diabetol. 2023; 60: 645-654.

34. Huang DD, Fan SD, Chen XY, et al. Nrf2 deficiency exacerbates frailty and sarcopenia by impairing skeletal muscle mitochondrial biogenesis and dynamics in an age-dependent manner. Exp Gerontol. 2019; 119: 61-73.

35. Western MJ, Welsh T, Keen K, Bishop V, Perkin OJ. Exercise snacking to improve physical function in pre-frail older adult memory clinic patients: a 28-day pilot study. BMC Geriatr. 2023; 23: 471.

36. Asghari M, Ehsani H, Toosizadeh N. Frailty identification using a sensor-based upper-extremity function test: a deep learning approach. Sci Rep. 2025; 15: 13891.

37. Huang J, Zhou S, Xie Q, Yu J, Zhao Y, Feng H. Digital biomarkers for real-life, home-based monitoring of frailty: a systematic review and meta-analysis. Age Ageing. 2025; 54: afaf108.