TITLE

Improving muscle strength and physical function in older people living with sarcopenia and physical frailty: not all exercise is created equal

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ARTICLE TYPE: PERSPECTIVE

WORD COUNT: 2434

FUNDING

A.A.S. is Director of the NIHR Newcastle Biomedical Research Centre in Ageing and Long-Term Conditions. The research was supported by the National Institute for Health and Care Research (NIHR) Newcastle Biomedical Research Centre based at the Faculty of Medical Sciences, Newcastle University, and the Newcastle upon Tyne Hospitals NHS Foundation Trust. The views expressed are those of the author(s) and not necessarily those of the NHS, the NIHR, or the Department of Health and Social Care.

CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

ABSTRACT

Exercise is an increasingly widely used treatment for older people across a range of clinical conditions including sarcopenia and physical frailty. Whilst exercise can have many benefits for older people, adaptations to exercise are specific to the exercise mode that is performed and not all exercise is created equal. The correct type of exercise, at the correct dose, needs to be prescribed to maximise effectiveness in treating sarcopenia and physical frailty where maintaining or improving muscle strength and physical function represent key aims. Resistance exercise (RE) is the most potent approach to improving muscle strength and physical function and should be prioritised within exercise programmes delivered to this group. RE programme design should be underpinned by the fundamental principles of exercise prescription in order to deliver an appropriate and individualised exercise dose to maximise the potential of RE as a treatment for older people living with sarcopenia and physical frailty.

KEYWORDS

Exercise, older people, muscle, sarcopenia, frailty, physical function

1. INTRODUCTION

It is widely recognised that physical activity is a key modifiable lifestyle behaviour which plays an important role in the prevention of long-term conditions [1]. Whilst physical activity can be considered to be any bodily movement produced by skeletal muscles that results in energy expenditure, *exercise* represents a subset of physical activity that is planned, structured and repetitive which aims to improve or maintain physical fitness or skill [2]. Whilst not a new strategy, exercise is increasingly being incorporated within the care of older people across a range of clinical contexts including surgical prehabilitation [3], acute hospitalisation [4] and in the treatment of the ageing syndromes of sarcopenia and frailty [5,6].

Sarcopenia—the progressive decline in skeletal muscle strength, mass and function [7]—and frailty—a multi-system impairment associated with increased vulnerability to stressors [8]—are important conditions that affect the current and future health status of a substantial number of older people. There is considerable overlap between these conditions as muscle strength, mass and function are central components of the physical phenotype of frailty [9]. The clinical relevance of sarcopenia is clear because of the high personal, social and economic burdens associated with the condition [7]. Muscle strength is an important determinant of physical function in older people (e.g., rising from a chair, gait speed) [10], while low muscle strength is associated is associated with a range of clinically relevant, adverse health outcomes including an increased risk of falls and fractures, reduced quality of life, loss of independence and mortality [7]. As such, treatments for older people living with sarcopenia and physical frailty should target improvements in muscle strength and function.

Exercise can improve muscle strength and physical function in older adults and is key for older people living with sarcopenia [11] and physical frailty [12]. However, ‘exercise’ is an umbrella term encompassing a wide variety of activities which can induce differential effects. Not all exercise is created equal for increasing muscle strength and function, meaning that the correct type of exercise, at the correct dose needs to be prescribed. This perspective will highlight issues relating to the prescription of exercise for older people living with sarcopenia and physical frailty.

2. NOT ALL EXERCISE IS CREATED EQUAL

2.1 Modes of exercise

A range of exercise modes can be prescribed to older people. These include resistance (or strength) exercise, aerobic (or endurance) exercise, balance exercise, flexibility exercise, and high-intensity interval training (Table 1). Resistance exercise (RE) requires muscles to work or hold against an applied force or weight with training effects most prominent across the neuromuscular system [13] including increases in muscle strength, size and quality [14]. Aerobic exercise involves large muscle groups performing dynamic activities for sustained periods [13] and leads to improvements in oxidative metabolism and cardiorespiratory fitness, but is less effective for improving muscle strength compared with RE [14]. Balance exercise, involving participants standing or moving in positions to challenge the body's ability to respond to different tasks or environments [15], and flexibility exercise, designed to preserve or extend range of motion around a joint, [13] play an important role in reducing falls risk for older people [16]. High-intensity interval training which involves performing repeated bouts of intense exercise interspersed with periods of rest or low intensity activity has the potential to positively impact multiple components of physical fitness (e.g., muscle power and cardiorespiratory fitness) simultaneously [17].

Table 1. Modes of exercise

Exercise mode	Typical activities	Primary outcomes
Resistance exercise	Resistance machines Elastic resistance bands Bodyweight exercises Free-weights (barbells, dumbbells)	↑ Muscle strength ↑ Muscle mass ↑ Muscle power
Aerobic exercise	Cycling Walking	↑ Cardiorespiratory fitness

	Swimming	
Balance exercise	Standing / Dynamic balance exercises Tai Chi Yoga	↑ Balance
Flexibility exercise	Stretching Yoga	↑ Flexibility
High-intensity interval training (HIT)	Cycling Stair climbing Uphill walking	↑ Cardiorespiratory fitness
↑ = increase		

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101 **2.2 Exercise to improve muscle strength and physical function**

102 A substantial body of evidence has demonstrated that RE is the most potent exercise mode to improve
103 muscle strength and physical function in older people [18,19]. Short-term programmes (6-12 weeks)
104 can induce clinically meaningful improvements across a range of outcomes in older men and women
105 [18,20]. Importantly, RE is feasible, safe and effective at increasing muscle strength and physical
106 function in those living with sarcopenia [21] and physical frailty [22]. For example, Aas et al. observed
107 significant increases in knee extensor strength and maximal gait speed following 10 weeks of twice
108 weekly RE in frail older men and women aged 86 ± 7 years [23]. Taken together, these findings indicate
109 that those working with older people living with sarcopenia or physical frailty should prioritise the
110 inclusion of RE within their exercise programmes.

111

112 **3. EXERCISE PRESCRIPTION**

113 Even those at very advanced age [24] and those living with sarcopenia [11] and physical frailty [6] can
114 benefit from structured exercise programmes. Notwithstanding this, it is important to avoid an '*anything*

is better than nothing' approach to exercise prescription as (i) a poorly designed exercise programme which is unlikely to induce beneficial effects is a waste of time and resources; (ii) prescribing the incorrect type of exercise may put older people at risk (e.g., brisk walking programmes may increase falls risk [25]). In order to realise the potential of exercise as a treatment, the appropriate type of exercise—at the correct dosage—needs to be prescribed in order to maximise beneficial effects [26]. As each mode of exercise has specific considerations for exercise programming, and exercise programmes for older people should aim to increase muscle strength, the following sections of this perspective will focus on RE.

3.1 Principles of exercise prescription

Exercise should be prescribed on an individual basis and be informed by the specific characteristics (e.g., baseline fitness, mobility, cognitive status, nutritional status, medication usage, exercise history), limitations and needs of each person. Older people should be actively involved in the design of the exercise programme with their preferences for delivery incorporated wherever possible. For example, our previous work has shown that the social benefits from exercising in a group are important to older people who also value individualised support and supervision from a personal instructor (e.g., physiotherapist, sport and exercise scientist) [27]. Effective RE prescription will incorporate the principles of specificity (responses to exercise are specific to the stimulus induced by the exercise dose), overload (a greater than habitual stress or load on the body is needed to induce adaptation) and progression (a gradual and systemic increase in stress placed on the body is necessary to induce continual adaptation over time) [28]. The response to exercise—and any resultant adaptation (training outcome)—is driven by the exercise stimulus (the stress placed on the body), which is largely determined by the exercise dose (Figure 1) [29]. Exercise programmes which are not individualised and fail to adhere to these fundamental principles of exercise prescription will be suboptimal.

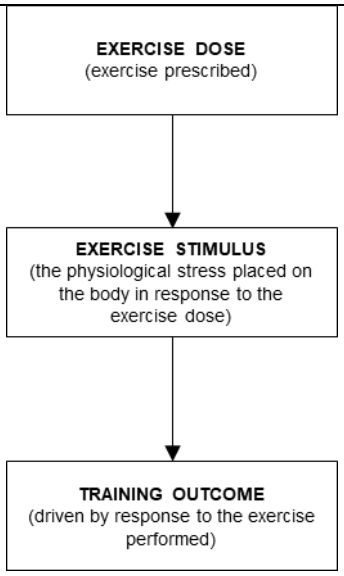

Figure 1. The exercise training process (see [29])

3.2. Designing resistance exercise programmes

Several RE variables can be manipulated to meet the needs and goals of the individual and the exercise programme. The primary considerations when designing RE programmes are training frequency, exercise selection, exercise intensity, exercise volume and rest intervals (Table 2) and manipulating these variables can modify the dose of RE [28].

Table 2. Resistance exercise variables

	Description
Training frequency	Number of exercise sessions per week
Exercise selection	Exercises performed during the exercise session
Exercise intensity	The relative or absolute load lifted
Exercise volume	Number of sets and repetitions of each exercise
Rest intervals	Amount of rest between exercises and between exercise sessions

The number of exercise sessions per week has important resource implications for the delivery of exercise programmes to older people and is a major determinant of the exercise dose. Two exercise sessions per week may be more effective than a single session, but performing three sessions per week

may not provide additional benefit [30]. A range of resistance exercise intensities can increase muscle strength in older people [18]. The choice of exercises included in an exercise programme [31], the volume of exercise performed [18] and how much rest is allocated within and between exercise sessions [32] are all important programme design considerations which influence the exercise dose. These variables can be manipulated to ensure that the exercise programme provides appropriate overload and progression (as discussed in section 3.1). For example, increasing the exercise volume is a useful method to ensure progression and overload as individuals become accustomed to the exercise dose.

As well as the variables outlined in Table 2, it is important to highlight that there are several other factors which can influence the RE dose including the speed that the exercises are performed at and the equipment used (e.g., free weights, resistance bands, resistance machines). While improvements in muscle strength and physical function are often observed simultaneously [33], this is not always the case [34] and it may be that RE performed with higher speed of movement is a more effective approach for improving measures of physical function in older people [35]. The duration of the exercise programme (i.e., the number of weeks/months) is also a key contributor to the overall exercise dose with longer duration programmes necessary to induce long-lasting benefits. As with exercise more broadly, not all RE is created equal for inducing improvements in muscle strength and physical function in older people and appropriate manipulation of programming variables is essential to maximise potential training effects.

3.3 A resistance exercise programme for older people living with sarcopenia and physical frailty

To date only limited evidence is available regarding the optimal RE programme for older people living with sarcopenia and frailty. As we have discussed, the optimal exercise programme is specific to each individual, yet practitioners and clinicians delivering exercise programmes need to be clear on what the foundations of a RE programme should consist of until further definitive information is available [28]. In Table 3 we present an illustrated example of what a RE prescription could look like for an older

179 person living with sarcopenia or physical frailty in an attempt to contextualise the information presented
180 earlier.
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Table 3. An illustrative resistance exercise prescription for sarcopenia and physical frailty	
Training frequency	2 sessions per week*
Exercise selection	A combination of upper and lower body exercises
Exercise intensity	Exercises performed with a relatively high degree of effort**
Exercise volume	1-3 sets of 6-12 repetitions
Rest periods	60-120 seconds between sets; 3-5 minutes between exercises 48 hours between exercise sessions
* One session per week may be enough for those individuals with very low levels of physical functioning or severe sarcopenia. However, the aim should be to progress to two exercise sessions per week over time. ** Muscles should feel tense, warm or shaky by the end of the first set of an exercise	

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183 For older people living with sarcopenia and physical frailty, the RE programme should involve a full
184 body workout, targeting muscles of the lower and upper body. Lower body exercises should be
185 prioritised within the programme (and performed earlier in the exercise session) because of their
186 importance for activities such as rising from a chair, ambulation and stair climbing. Suggested exercises
187 to incorporate within the RE programme are presented in Table 4. Although the optimal intensity for
188 increasing muscle strength for older people living with sarcopenia and physical frailty remains uncertain
189 [36], the most consistent message to date is that RE should be performed with a relatively high degree
190 of effort (e.g., muscles should feel tense, warm or shaky by the end of the first set of an exercise). Over
191 time, the RE programme can progress to include some RE exercises which are performed at higher
192 speed once the individual has developed correct technique and can perform the movements safely.
193 However, the early stages of the programme should focus on increasing muscle strength rather than
194 power. Functional exercises (e.g., repeated sit to stands) which mimic activities of daily living can also

be incorporated within the exercise programme [37], performed either within the exercise sessions or as a supplement at home in between sessions.

Table 4. Example exercises to include within a RE programme for older people with sarcopenia and physical frailty

	Muscles	Example exercises
Lower body	Knee extensors (Quadriceps)	Knee extension, leg press, squat, sit to stand
	Knee flexors (Hamstrings)	Leg curl, standing knee flexion
	Gluteals	Leg press, squat
	Hip abductors/adductors	Seated marching, standing hip abduction
	Ankle dorsiflexors	Toe raises
	Ankle plantarflexors	Calf raises
Upper body	Chest, Triceps	Chest press
	Back (Trapezius / Rhomboid)	Seated row
	Latissimus dorsi, Biceps	Pull down
The above exercises are illustrative examples which can be delivered in several ways dependent on equipment availability (e.g., weight machines, resistance bands or free weights where appropriate), functional limitations and personal preference to best meet the needs of the individual.		

It is important to highlight that a thorough assessment of health status (e.g., disease presence, symptoms, functional limitations) should be undertaken at the start of an exercise programme to ensure that exercise prescription is tailored to the individual, and the conditions they live with, and to identify any contraindications to exercise [38]. For example, exercises that are safe and effective for an older person

who has had a recent hip fracture, will be different to those without this history [39]. Whilst this paper has focused on highlighting the importance of RE for counteracting declines in muscle strength, older people are likely to experience decline across multiple physiological systems simultaneously (e.g., reduced cardiorespiratory fitness and muscle strength). Therefore, a comprehensive exercise programme will likely include a combination of exercise modes [40] as opposed to RE alone, in order to maximise exercise training induced gains [41].

4. FUTURE DIRECTIONS

Despite the increased appreciation and application of exercise as a treatment strategy for older people [42], more work is needed to optimise the prescription and delivery of RE to older adults living with sarcopenia and frailty [43]. Translational research, which seeks to translate lab-based scientific discoveries into improved treatments for patients, has a key role to play. For example, there remains considerable uncertainty about what the optimal dose of exercise for older people living with sarcopenia and physical frailty is, while determining the minimal effective dose of RE is an important question because of the practical implications for patients and clinicians. Future work should also explore the potential of combining RE with other exercise (e.g., blood flow restriction training, high-intensity interval training, electrical stimulation), pharmacological and nutritional approaches to maximise the potential of RE. It is important that this future work includes individuals who live with multiple long term conditions (MLTC) as well as sarcopenia and physical frailty in order to reflect the majority of patients seen in clinical practice [44]. Low muscle strength is prevalent in those living with MLTC, meaning that this group are an important target for therapeutic intervention [45]. Exercise appears to be safe and beneficial in those living with MLTC [46], but more evidence is needed involving RE which is focused on sarcopenia and frailty related outcomes in this population.

As well as the questions relating to exercise programme design that remain unresolved, we need to understand more about how best to implement RE for older people living with sarcopenia and frailty

and what RE currently being delivered in clinical practice looks like. It is important that exercise programmes are designed and delivered by those who are appropriately qualified and experienced and there is real potential for sport and exercise scientists to support physiotherapists and exercise practitioners in the delivery and implementation of exercise to older people in clinical practice [47]. However, further ongoing collaborative discussion is needed to understand how these disciplines, and others involved in the care of older people (e.g., geriatricians, dieticians, psychologists, occupational therapists), can work together to best support patients. Physicians have a significant role to play in building awareness and advocating the potential of RE as part of a treatment strategy for older people living with sarcopenia and physical frailty [48]. For older people, doctors are a valuable and credible source to support engagement in exercise programmes [27,49]. More directly, clinical practice has an important role to play in screening and identifying those who have sarcopenia, or are at greatest risk of developing sarcopenia, so these individuals can be prioritised for intervention [50].

5. CONCLUSION

Exercise is an increasingly widely used treatment strategy for older people including those living with sarcopenia and physical frailty. However, when it comes to improving muscle strength and physical function, not all exercise is created equal. Resistance exercise is the most potent strategy to improve muscle strength and physical function, but it needs to be prescribed on an individual basis and at an appropriate dose for it to be effective. The fundamental principles of RE prescription need to be adhered to in order maximise the potential of RE to improve outcomes for older people living with sarcopenia and physical frailty.

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