

# Preserving Mobility in Older Adults with Physical Frailty and Sarcopenia: Opportunities, Challenges, and Recommendations for Physical Activity Interventions

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**Abstract:** One of the most widely conserved hallmarks of aging is a decline in functional capabilities. Mobility loss is particularly burdensome due to its association with negative health outcomes, loss of independence and disability, and the heavy impact on quality of life. Recently, a new condition, physical frailty and sarcopenia, has been proposed to define a critical stage in the disabling cascade. Physical frailty and sarcopenia are characterized by weakness, slowness, and reduced muscle mass, yet with preserved ability to move independently. One of the strategies that have shown some benefits in combatting mobility loss and its consequences for older adults is physical activity. Here, we describe the opportunities and challenges for the development of physical activity interventions in people with physical frailty and sarcopenia. The aim of this article is to review age-related physio(patho)logical changes that impact mobility in old age and to provide recommendations and procedures in accordance with the available literature.

**Keywords:** physical exercise, muscle mass, strength, walking, balance, better aging

## Introduction

One of the major challenges rising from the aging of the population is to avoid mobility impairment. Mobility is defined in a broad context by Webber et al<sup>1</sup> as the ability to move oneself (either independently or by using assistive devices or transportation) within environments that expand from one's home to the neighborhood and to regions beyond. Approximately one third to one half of individuals aged 65 years or older report difficulties related to walking or climbing stairs.<sup>1</sup> Furthermore, mobility limitation during aging is associated with loss of strength and/or function that characterizes sarcopenia.<sup>2-4</sup> Sarcopenia is described by the EWGSOP2 as a progressive and generalized skeletal muscle disorder that is associated with increased likelihood of adverse outcomes including falls, fractures, physical disability, and mortality.<sup>5</sup> Sarcopenia is now formally acknowledged as a muscle disease with an ICD-10-MC diagnosis code.<sup>6</sup> This medical syndrome of sarcopenia may reflect a gradual decline that impairs functional reserve in a dynamic process. On a parallel track, adverse events can drastically modify the health status of a person, which refers to the concept of frailty. An international group of experts has defined frailty as a clinical state in which there is an increase in an individual's vulnerability for developing increased dependency and/or mortality when exposed to a stressor. Frailty can occur as the result of a range of diseases and

medical conditions.<sup>7,8</sup> In this context, a frail individual is characterized by weak functional abilities that occur large deterioration after a minor illness.<sup>9</sup> In order to counteract the effect of the aging process and avoid moving toward a state of frailty, functional reserve has to be strengthened, notably by physical activity. Physical activity is used as an umbrella term including exercise, leisure time physical activity, or even sports.<sup>10</sup> Physical activity is defined as any bodily movement produced by skeletal muscles that require energy expenditure, whereas exercise is a planned, structured, repetitive movement including progression with regard to intensity.<sup>10</sup>

Frailty, especially associated with sarcopenia syndrome, is the main pivotal point to establish a preventive intervention program. Actually, there is evidence that without intervention, sarcopenia and frailty often lead to disability, falls, and a decline in quality of life.<sup>11</sup> There is also an increased risk of hospitalization and death.<sup>7,8</sup> That is why prevention of loss of mobility becomes a priority in this population.

Regular physical activity, exercise, and leisure time physical activity including sports, combined with an adequate diet can prevent sarcopenia and consequently frailty. A multicomponent exercise training program, which includes aerobic, strength, and balance exercises, is considered to be the most effective tool for improving mobility and gait, increasing muscle mass and strength, decreasing falls, enhancing functional performance of activities of daily living, and improving quality of life.<sup>12</sup>

This article first summarizes the functional alterations occurring in the sarcopenic and frail population. In the second part, the article highlights opportunities and challenges to prevent functional impairment, and mobility impairment through a physical activity program based on randomized clinical trials: LIFE and SPRINTT. Finally, the article provides recommendations for maintaining and improving mobility and functional performance in this specific population.

## Physiological Changes in the Older Population: Sarcopenia and/or Frailty

### Muscle Strength and Power

In old age, the most important impact on mobility arises from changes in muscle strength and power. “Strength” can be defined as the maximum force generation capacity of an individual, whereas “power” refers to the product of

force and velocity of contraction.<sup>13–15</sup> Several studies have demonstrated that strength capacities start to decline around the age of 30 years<sup>16,17</sup> and that the decline increases at the rate of about 12% to 15% per decade after the fifth decade, with an even faster decline after 60 years.<sup>18</sup> Longitudinal studies have reported that strength decreases about 2.5% and 1.5% per year after sixty years old at the knee and elbow joints, respectively.<sup>19</sup> It has consequently been suggested that alteration of muscular strength could be muscle-specific.<sup>20,21</sup> Skelton et al demonstrated that power declines with aging at an even more rapid rate than strength.<sup>15</sup> The origins of strength and power decline with aging are multifactorial. In two reviews, Clark and Manini<sup>22</sup> and Vandervoort<sup>23</sup> characterized the loss of neuromuscular strength with aging. In these reviews, the authors reported that neuromuscular strength could be directly influenced by changes in both the nervous system and the muscular system. Regarding the nervous system, the authors indicated that alteration of command drive,<sup>24–31</sup> spinal reflex excitability,<sup>32,33</sup> and motor unit discharge rate<sup>34</sup> can alter strength production in older people. In the muscular system, alterations were observed in muscle mass size,<sup>3,35</sup> muscular architecture,<sup>36</sup> and excitation–contraction coupling,<sup>37</sup> which can be influenced by reduction of androgen secretion and growth factor.<sup>38,39</sup> Studies over the last four decades have demonstrated that physiological deficiencies are clearly associated with functional performance.<sup>15,40–43</sup>

Related to physical function, there is evidence that knee extensor strength is an excellent predictor of dependency and survival, and that leg power is a stronger predictor of mobility loss than strength.<sup>40,44–46</sup> Bean et al<sup>40</sup> found that leg power was strongly predictive of physical performance in 45 participants aged about 73 years (75% women), highlighting a significant relationship with stair climb time, chair stand, tandem gait time, habitual gait velocity, maximal gait velocity and Short Physical Performance Battery (SPPB) tests (Table 1). Other studies have reported that handgrip strength is strongly associated with lower limb muscle power and physical function of daily living.<sup>47,48</sup> In conclusion, it can be stated that muscle strength and power decline at different rates, with power decreasing more rapidly than strength. While many factors contribute to strength and power decline, muscle mass is of key importance.

### Muscle Mass

As previously mentioned, the combination of low muscle strength, low physical performance, and reduction of

**Table I** Overview of Tests Available for the Assessment of Balance, Gait, and Lower Extremity Function

Tested Function	Name	Description	Interpretation
Balance Gait Lower extremity function	Short Physical Performance Battery (SPPB) <sup>179</sup>	<p>The SPPB involves three subtasks: balance test, habitual gait speed, and the 5-repetition chair stand test. Possible scores range from 0 to 12.</p> <p>Balance test: Ability to stand for 10 seconds with feet in three different positions:</p> <ul style="list-style-type: none"> <li>- Side-by-side (scored from 0–1)</li> <li>- Semi-tandem (scored from 0–1)</li> <li>- Full-tandem (scored from 0–2)</li> </ul> <p>Gait speed test: Timed 4-min walk at usual pace:</p> <ul style="list-style-type: none"> <li>- 0, unable to do the walk</li> <li>- 1, if time is &gt; 8.7 seconds</li> <li>- 2, if time is 6.21 to 8.70 seconds</li> <li>- 3, if time is 4.82 to 6.20 seconds</li> <li>- 4, if time is &lt;4.82 seconds</li> </ul> <p>Chair stand test: Time to rise from a chair five times as quickly as possible:</p> <ul style="list-style-type: none"> <li>- 0, unable to complete five chair stands or completes stands in &gt;60 seconds</li> <li>- 1, chair stand time is ≥ 16.70 seconds</li> <li>- 2, chair stand time is 13.70 to 16.69 seconds</li> <li>- 3, chair stand time is 11.20 to 13.69 seconds</li> <li>- 4, chair stand time is ≤ 11.19 seconds</li> </ul>	<p>Total balance test score: __/4 points Gait speed test score: __/4 points Chair stand test score: __/4 points Total score __/12 points (sum of points above) Score and classification of limitation: 0–3: Severe 4–6: Moderate 7–9: Low 10–12: Very low/absent</p>
Balance Gait	Tinetti balance assessment tool <sup>180</sup>	<p>The Tinetti balance assessment tool consists of balance and walking tests. Possible scores range from 0 to 28.</p> <p>Balance maneuvers assessment (eight items)</p> <ul style="list-style-type: none"> <li>- Sitting balance scored from 0–1</li> <li>- Rising from chair scored from 0–4</li> <li>- Immediate standing balance (first 5 seconds) scored from 0–2</li> <li>- Prolonged standing balance scored from 0–2</li> <li>- Withstanding nudge on chest scored from 0–2</li> <li>- Standing balance with eyes closed scored from 0–1</li> <li>- Turning 360 degrees scored from 0–2</li> <li>- Sitting down scored from 0–1</li> </ul> <p>Gait observations assessment (eight items)</p> <ul style="list-style-type: none"> <li>- Initiation of gait scored from 0–2</li> <li>- Step length scored from 0–2</li> <li>- Step height scored from 0–2</li> <li>- Step continuity scored from 0–2</li> <li>- Step symmetry scored from 0–1</li> <li>- Walking stance scored from 0–1</li> <li>- Amount of trunk sway scored from 0–1</li> <li>- Path deviation scored from 0–2</li> </ul>	<p>Total balance test score: __/15 points Total gait test score: __/13 points Total score __/28 points (sum of points above) Score and risk of falls: &lt;19: High 19–23: Moderate &gt;24: Low</p>
Balance	One-leg balance test <sup>181</sup>	The one-leg balance test assesses the ability to stand upright on one leg.	<p>Score and risk of falls: &lt;5 second: High 6–29 seconds: Moderate &gt;30 seconds: Low</p>

(Continued)

Table I (Continued).

Tested Function	Name	Description	Interpretation
Balance	Berg Balance Scale (BBS) <sup>182</sup>	<p>The BBS tests balance function by assessing the performance of functional tasks. Possible scores range from 0 to 56. Assessments (14 items scored from 0–4)</p> <ul style="list-style-type: none"> <li>- Sitting to standing</li> <li>- Standing unsupported</li> <li>- Sitting with back unsupported but feet supported on floor or on a stool</li> <li>- Standing to sitting</li> <li>- Transfers</li> <li>- Standing unsupported with eyes closed</li> <li>- Standing unsupported with feet together</li> <li>- Reaching forward with outstretched arm while standing</li> <li>- Pick up an object from the floor from a standing position</li> <li>- Turning to look behind over left and right shoulders while standing</li> <li>- Turn 360 degrees</li> <li>- Place alternate foot on step or stool while standing unsupported</li> <li>- Standing unsupported one foot in front</li> <li>- Standing on one leg</li> </ul>	<p>Score and risk of falls:</p> <p>0–20: High 21–40: Moderate 41–56: Low</p> <p>A change of at least eight points indicates an actual change in function between two assessments.</p>
Gait Lower extremity function	Timed Up and Go (TUG) <sup>183</sup>	<p>TUG is used to assess mobility. Participant is instructed to rise from a chair, walk three meters, turn around a physical marker, walk back to the chair, and sit down.</p>	<p>Score and classification of mobility:</p> <p>&lt;10 seconds: Normal 10–20 seconds: Moderate 20–30 seconds: Low &gt;30 seconds: Very low</p>
Gait	400-m walk test <sup>184</sup>	<p>The 400-m walk test assesses mobility over a long track. Participant is instructed to walk at normal pace. The 400-meter path is materialized with two physical markers located 20 meters apart. During the test, the participant may not use assistive devices (except for a cane). Criteria for interrupting the test are palpitations, chest pain, constriction, feeling of oppression, dyspnea, sensation of fainting, empty head, or postural instability, pain in the lower limbs, vertigo, and muscle fatigue.</p> <p>The 400-m walk time is measured using a manual chronometer or an optoelectronic system with two photocells connected to a digital chronometer.</p>	<p>Participant unable to complete the test within 15 min is considered to be mobility disabled.</p>
Gait	6-Minutes Walking Test (6-MWT) <sup>185</sup>	<p>The 6-MWT assesses mobility and cardiorespiratory fitness. Participant is instructed to walk at brisk pace he/she can maintain throughout the test. The path is materialized with two physical markers located at 20 meters apart. During the test, the participant may not use assistive devices (except for a cane). Criteria for interrupting the test are palpitations, chest pain, constriction, feeling of oppression, dyspnea, sensation of fainting, empty head, or postural instability, pain in the lower limbs, vertigo, and muscle fatigue.</p> <p>The 6-MWT distance is calculated by the sum lap distance (40 m per lap) plus the distance walked during the last lap.</p>	<p>Participant unable to complete at least 332 meters (walking speed 0.8 m/s) is considered to be mobility disabled.</p>

muscle mass characterize sarcopenia.<sup>3–5,49</sup> Sarcopenia is considered a critical point to determine the frail population and can be influenced by several factors. In a recent overview, Marzetti et al<sup>3</sup> reported that sarcopenia can be impacted by (i) personal factors such as age, early life events, low birth weight, and genetic characteristics, (ii) hormonal factors (eg, testosterone, estrogens, growth hormone, insulin-like growth factor-1), chronic low-grade inflammation, and mitochondrial dysfunction, (iii) lifestyle habits such as decrease in food and protein intake, sedentary behavior or reduced physical activity, alcohol abuse, tobacco use, and bed rest, (iv) chronic health conditions such as cognitive impairment, diabetes, and advanced stage organ diseases.

The literature has shown that after the seventh decade, muscle mass decreases by 4.7% and 3.7% per decade in men and women, respectively.<sup>14</sup> Using dual energy X-ray absorptiometry (DXA) to examine muscle mass in 433 individuals (180 women) aged 18–94 years, Kyle et al<sup>50</sup> reported that muscle mass is almost steady from 18 to 60 years, and declines after 60 years. In a magnetic resonance imagery (MRI) study in 468 individuals (200 women), Janssen et al<sup>51</sup> also reported that the rate of loss of muscle mass of upper limbs decreases less than twice the rate of loss of lower limbs. Further, men showed larger age-related muscle mass decrease compared to women.<sup>52</sup>

Muscle mass can be estimated with several techniques such as anthropometric measurements, bioelectrical impedance analysis (BIA), computed tomography (CT), MRI, and DXA. Each of these techniques has advantages and disadvantages in terms of cost, availability, ease of use and time consumption.<sup>3</sup> Compared to the gold standard for quantifying muscle mass, ie CT and MRI, DXA may, due to the minimal radiation received by the patient, be the best way of differentiating fat and lean tissues. However, DXA scan is not portable, which limits its use in a large-scale population. To overcome this issue, BIA is inexpensive, easy to perform, readily reproducible, appropriate for ambulatory as well as bedridden patients, and more accurate than anthropometry. All in all, DXA could be considered as the best gold standard alternative to quantify muscle mass in research, and BIA as a valid portable alternative.

While the relationship between muscle mass decline and negative outcomes is still debated in the literature,<sup>14</sup> recent studies provide robust evidence that sarcopenia, including loss of muscle mass, is associated with falls, physical frailty, and disability.<sup>3</sup> Older adults with

sarcopenia are reportedly less active than people without sarcopenia.<sup>53,54</sup> Furthermore, different studies have shown that the older population with sarcopenia has a greater risk of death (whatever the causes) compared with nonsarcopenic people.<sup>55–59</sup> From another perspective, the decrease in the circulating levels of specific hormones has been associated with both sarcopenia and osteoporosis, showing that the two processes follow a similar path.<sup>60</sup> An observational study recently carried out among 68 prefrail older persons aged between 65 and 95 years reported that those with osteosarcopenia were at higher risk of fractures or functional decline than those with either sarcopenia or osteoporosis.<sup>61</sup> Further, the authors showed that the performance on the handgrip strength, chair rise and sit-to-stand tests were significantly lower in patients with osteosarcopenia than in those with sarcopenia or osteoporosis alone. Finally, it has been reported that the sarcopenic older population was more than threefold likely to fall than those without sarcopenia.<sup>62–64</sup>

## Balance and Postural Control

It has been well documented that postural control decreases and risk of falls increases with aging. As a result, falls are a common event in older adults, with about one third of persons 65 years and older experiencing a fall event yearly. This number increases to nearly 50% in the age group 80 years and above.<sup>65</sup> The decline in balance and postural control are multicausal. To maintain upright standing, the neuromuscular system has to generate appropriate muscular contraction involving complementary input from the visual, proprioceptive, exteroceptive and vestibular systems.<sup>66–71</sup> Age-related alteration in these different systems results in decline of postural control.<sup>72–74</sup> Experimental studies have shown that older persons are less able to regulate postural control when sensory information is manipulated or removed.<sup>72,74–76</sup> In a challenging condition, such as one-leg stance, maintaining upright standing is more energy-consuming in older than in their young counterparts.<sup>77–79</sup> Strength capacity is also useful to discriminate fallers from nonfallers, showing that the former group is weaker than the latter.<sup>80</sup> It has also been shown that aging is associated with a progressive shift from spinal to supraspinal pathways to regulate leg muscle activity in an upright standing position.<sup>81</sup> This finding is supported by experimental studies reporting that the frail population could require more cognitive resources to maintain upright standing, and consequently increase the delay of postural control adjustment in comparison with healthy older adults.<sup>82–84</sup> While there is no clear evidence of specific system alteration between frail

and nonfrail, and sarcopenia vs nonsarcopenia populations, clinical studies have shown more conclusive results.

From a meta-analysis, Yeung et al<sup>85</sup> recently reported significant higher risk of falls in people with sarcopenia than without. Further, in a systematic review and meta-analysis of 10 studies with 10,073 participants, Zhang et al<sup>86</sup> concluded that sarcopenia is a risk factor for falls among community-dwelling older people, but not in nursing home residents. The authors provided several explanations for this counterintuitive finding.<sup>87,88</sup> First, nursing-home residents may have limited mobility due to their poorer health status, which may moderate the effect of sarcopenia on falls.<sup>89</sup> In addition, in community-dwelling older adults falls were reported with questionnaires, whereas falls in nursing homes reported by nurses may be underestimated. With regard to gender, Zhang et al<sup>86</sup> indicated that old men with sarcopenia had a higher risk of falls than older persons in mixed gender groups. These results are supported by the fact that muscle mass decreases in men are generally twice as great than in women.<sup>90,91</sup> In addition to sarcopenia, a systematic review and meta-analysis by Kojima<sup>92</sup> demonstrated that both frailty and prefrailty are significant predictors of future falls among community-dwelling older people. This could result from decreased functional reserve capacity in multiple physiologic systems and increased vulnerability to stressors such as accidents, disease symptoms, or adverse drug reactions.<sup>93</sup> All in all, the literature has demonstrated an age-related increased risk of falls, especially in persons with sarcopenia and the frail population. The increased risk of falls with aging is intrinsically linked to the deterioration of the dynamic balance generated during walking and, more generally, when in relation to mobility.

## Walking and Mobility

Locomotion, defined as a motor action that changes the location of the entire body within the environment, is a common daily activity in human beings. Walking speed, representing the capacity of walking, declines slightly until the sixth decade, and decreases at a faster pace thereafter.<sup>94,95</sup> In a cross-sectional study, Samson et al<sup>95</sup> evaluated the preferred walking speed over a 12-meter walkway in 118 women and 121 men aged from 19 to 90 years. The authors found an age-related decrease of gait parameters with an alternation not only in walking speed, but also in stride length. However, modification of walking patterns with age has not appeared consistently throughout the literature. Compared to young adults, some studies have reported greater stride width in older adults,<sup>96–98</sup> while

other studies have indicated lesser stride width with older age.<sup>99</sup> Ko et al<sup>100</sup> revealed that stride width at preferred walking speed was narrower in middle-age (32–57 years) than in old adults (58–78 years) at maximum speed, while it was wider in oldest old group (79–93 years). The authors concluded that the walking pattern alteration could be different during the aging process, and could also depend on testing conditions. The impact of the methods used to obtain walking/gait speed was also addressed by Ng et al<sup>101</sup> and Wang et al<sup>102</sup> To explain alterations of walking capacity and patterns, different hypotheses have been put forward. In the Baltimore Longitudinal Study of Aging, a significant correlation between walking speed and maximal voluntary contraction of knee extensor was shown.<sup>100</sup> The authors' interpretation was that a decrease of knee extensor muscle strength could explain the decline of walking speed with aging. Callisaya et al<sup>103</sup> found an association among white matter atrophy and walking speed, step length and cadence. The authors suggested that these results strengthened the evidence of a causal relationship between brain aging and walking decline. In a recent systematic review and meta-analysis, Peel et al<sup>104</sup> supported these results by reporting an association between gait speed performance and global cognitive function in community-dwelling older people throughout 16 longitudinal (15,662 participants) and 20 cross-sectional (13,848 participants) studies. This meta-analysis showed reduction of gait speed of 0.11 m/s in persons with cognitive impairment, 0.20 m/s in those with mild dementia, and of 0.41 m/s in those with moderate dementia, compared to cognitively intact older adults. In addition to cognitive functions, walking speed may be related to older people's mobility.

While 85% of people at the age of 60 years have a normal gait, this proportion drops to 18% in people aged 85 years. In a predictive model study, Guralnik et al<sup>179</sup> reported that walking speed is a good predictor of daily living activity disability and mobility impairment. Furthermore, age-related walking speed decline has been associated with increased risk of falls,<sup>105</sup> quality of life,<sup>106</sup> health status,<sup>107</sup> physical function, and mobility,<sup>108,109</sup> cognitive decline and dementia,<sup>110–112</sup> and early mortality.<sup>113</sup> More specifically, Studenski et al<sup>113</sup> using individual data from 34,485 community-dwelling older adults (from nine cohort studies) with a follow-up longer than five years, evaluated the relationship between gait speed and survival. The authors reported that survival increases across the full range of gait speeds, with a gait speed of around 0.8 m/s at the median life expectancy at most ages for both sexes.

They reported that gait speed, adjusted by age and sex, provided as accurate as predictions based on age, sex, use of mobility aids, and self-reported function or as predictions based on age, sex, chronic conditions, smoking history, blood pressure, body mass index, and hospitalization. All in all, the authors suggested that gait speed could be used in a simple way as an indicator of the health of older persons, and might help to identify populations that could benefit from preventive intervention. For all these reasons, walking speed has been identified as the sixth vital sign in geriatric assessment,<sup>114</sup> and could be the main indicator of mobility loss in the older population. In addition to motor function impairment, aging has an impact at the molecular and cellular level.

## Molecular and Cellular Factors

Aging is accompanied by changes in molecular, cellular and organ level and modulated by genetic, behavioral and environmental factors. One of the most important factors in this area is the immune dysregulation producing high blood levels of pro-inflammatory immunogenetic stimulation.<sup>115</sup> High levels of circulating pro-inflammatory markers, eg IL-1, IL-6 as well as C-reactive protein, transforming growth factor  $\beta$  and others are responsible for immune dysregulation and increased inflammation in older age. This pro-inflammatory status is often known as “inflammaging”.<sup>115</sup> Epidemiological studies have demonstrated the negative impact of inflammaging on cardiovascular disease, neurological disorder such as depression or dementia, and furthermore on global health indicators such as frailty, sarcopenia, and mobility limitation.<sup>115</sup>

There is increasing evidence that low physical activity levels increases the accumulation of visceral fat, adipose infiltration by pro-inflammatory immune cells and persistent low-grade inflammation.<sup>116</sup> In his review article Philipps<sup>117</sup> provided evidence that long-term physical activity modulates age-related cellular and molecular changes. Physical activity has a positive impact on the inflammatory processes and increases the resilience stress response.<sup>117</sup>

Given that aging induces alterations in strength and power, muscle mass, balance and postural control, walking and mobility, physical activity or an exercise program provide opportunities to reduce and/or to stave off some of the negative effects of aging.

## Opportunities

Evidence suggests that regular physical activity provides substantial health benefits and reduces risk of chronic

diseases. In a systematic review, Paterson and Warburton<sup>118</sup> demonstrated that inactive older persons ran an increased risk of functional limitations. Interestingly, the risk of physical limitations decreased on average about 20% if the person was only “somewhat active” (level 1 of physical activity). Moderate physical activity reduced even further the risk of functional limitations. It is commonly understood that any type of physical activity, even at low intensity, is one of the most effective strategies designed to counteract the onset of chronic diseases, eg Type II diabetes and cardiovascular disease,<sup>119</sup> and to support healthy aging. In addition, physical activity decreases mobility limitations, and supports independent status as well as quality of life.<sup>120</sup> Taylor<sup>119</sup> stated that physical activity should be regarded as an actual “medicine” due to its large array of health benefits. Hence, several recommendations for older persons to be physically active have been published.<sup>121–123</sup> These recommendations propose similar advice: an older person should be physically active for about 30 min per day adding up to 150 min per week of moderate physical activity. One has to keep in mind that the term “physical activity” incorporates all movements that increase energy expenditure. Another important point in all of the recommendations addresses the intensity level by proposing moderate or even vigorous levels of physical activity, and the inclusion of strength and balance exercises.<sup>121,122</sup> With regard to intensity, brisk walking may be considered as moderate and running or jogging as vigorous physical activity.<sup>122</sup> Nevertheless, most older adults rarely reach moderate-to-vigorous intensity on a daily basis and walking at light intensity constitutes the major part of physical activity in which they engage.<sup>124</sup> Knowing that additional health effects arise from engaging in a higher level of physical activity, especially in structured exercise programs,<sup>119,121</sup> greater efforts should be made to increase the participation of older adults.

With regard to function, a recent review by Steffl et al<sup>54</sup> demonstrated that physical activity also has positive effects on physical function, eg modifying the sarcopenic process. This is in line with the findings by Marzetti et al<sup>125</sup> With regard to cognitive function, evidence is evolving that physical activity and exercise also have positive effects on cognitive capacities such as memory, attention, or executive function. Although the effects of physical activity on cognitive function vary with regard to physical activity modality (aerobic, strength, or other type), intensity (light, moderate, or vigorous), and various cognitive domains,

evidence exists that older persons benefit from physical activity or exercise training with regard to cognitive functions and in some cases maintain this benefit over the long-term.<sup>126–130</sup>

With regard to the important issue of fall events in older persons, recent reviews have underlined the importance of targeted, planned, and structured exercise intervention including progressive strength training and challenging balance exercise.<sup>131,132</sup> It is important to realize that in fall prevention the subcategory of exercise, not the broad-based term of physical activity, has demonstrated positive effects.

Over recent years another construct has been recognized as a key factor: sedentary behavior, which has been found to be an important risk factor for adverse events in older adults. In an EU project, the determinants of sedentary behavior were defined over the life span, and especially in older persons.<sup>133</sup> Sedentary behavior, or the formal construct of inactivity, has not only demonstrated negative health impact on an individual level, but has also generated deleterious economic and social consequences. Inactivity was responsible for about 5.3 to 5.7 million deaths globally from noncommunicable diseases, which could be prevented if people who were inactive were instead sufficiently active.<sup>134</sup> These findings are independent of physical activity levels.<sup>135</sup> Not surprisingly, in most recommendations reduction of sedentary behavior has been included, with the goal of reducing sitting time.<sup>122</sup> Several studies have demonstrated the negative health impact of sedentary behavior.<sup>133,136</sup> Nevertheless, recent research has demonstrated that although replacing sedentary behavior with moderate-to-vigorous physical activity is associated with reduction of sarcopenia rates and with better performance across its determinants in a dose-response fashion, light physical activity also seemed protective.<sup>137</sup>

In conclusion, these results suggest that even light physical activity, in which most older adults can partake, could contribute to healthy aging, by counteracting one of the most important contributors to functional loss, sarcopenia.<sup>138</sup> It is evident that physical activity has demonstrated beneficial health effects in older persons, whereas the other side of the coin—sedentary behavior—has only lately been recognized as equally important. Further research has demonstrated the positive effects of even a small increase in physical activity levels on health outcomes.<sup>139</sup> While regular physical activity offers clear

opportunities to improve health, many challenges are encountered by the older population.

## Challenges

Older persons constitute the most inactive cohort in population-based studies.<sup>140,141</sup> In Australia, among persons aged 75 years and older, about 75% are reported not to meet recommended physical activity levels.<sup>140</sup> Older persons' motivation to engage in physical activity is influenced by behavioral (eg perceptions, self-efficacy) and environmental factors (eg access, availability). Furthermore, different domains add to the complexity of engaging older persons in physical activity: type and intensity of physical activity, group or individual physical activity, organizational issues (morning or afternoon).<sup>120,140</sup> The need to communicate and translate research findings on the positive effects of physical activity has been recognized lately by investigating the perception of older persons. Communication models such as the elaboration likelihood model (ELM) by Petty and Cacioppo<sup>142</sup> or behavior-related psychological models such as the health belief model (HBM) or integrated behavior change model (ICBM) have been used. Most models of increased physical activity share as a central point self-efficacy, norms and values, as well as attitudes.<sup>143</sup> Being “too old” or “at my age, physical activity does not help” are attitudes that pose a barrier to adhering to physical activity recommendations.<sup>144,145</sup> Low self-efficacy likewise poses a barrier for uptake or maintenance of physical activity or exercise programs.<sup>146</sup> Taking into account the specificities of the two domains, it is of utmost importance to phrase invitations in a positive manner and to address older persons' perceptions of physical activity. In other words, older persons or future participants in research projects on exercise intervention should be persuaded that they are able to take part or carry out the proposed physical activity.<sup>147</sup>

Several factors that prevent older persons from being physically active have been reported. In a systematic review, Baert et al<sup>148</sup> provided a theoretical framework for investigating barriers to physical activity in older adults. The social-ecological model used in this systematic review provides different levels to be addressed when investigating these barriers.<sup>148</sup> The model differentiates intrapersonal, interpersonal, community, and policy-based barriers. A similar differentiation method was used by Bauman et al<sup>149</sup> who also identified interpersonal, intrapersonal and extrapersonal factors such as environment and policy. On an intrapersonal level, for example, several factors have been identified as barriers. Baert et al<sup>148</sup>



identified health status as a barrier for physical activity, which is in line with the findings of Newson and Kemp<sup>150</sup> and Lubs et al<sup>151</sup>. However, health status can act as an enabler and motivation to become physically active and thereby improve health outcomes.<sup>152,153</sup>

Further expertise to an increased level of physical activity or exercise programs may be found in the fall prevention research field.<sup>154–157</sup> Elskamp et al<sup>154</sup> detected, on an individual level, the following reported reasons for nonactivity: lack of time, impaired mobility or “being too healthy”. Furthermore, one study showed that fall risk perception was related to fear of vulnerability, maintenance of autonomy, and interpretation of risk.<sup>158</sup>

In conclusion, increasing physical activity or uptake of exercise intervention in older persons is a challenging and complex task. Several aspects of theoretical psychological models need to be taken into account, and positive wording as well as the highlighting of positive outcomes are of utmost importance in strengthening older persons’ belief that they can perform or take part in the proposed activity to follow the recommendations.

## Recommendations and Procedures

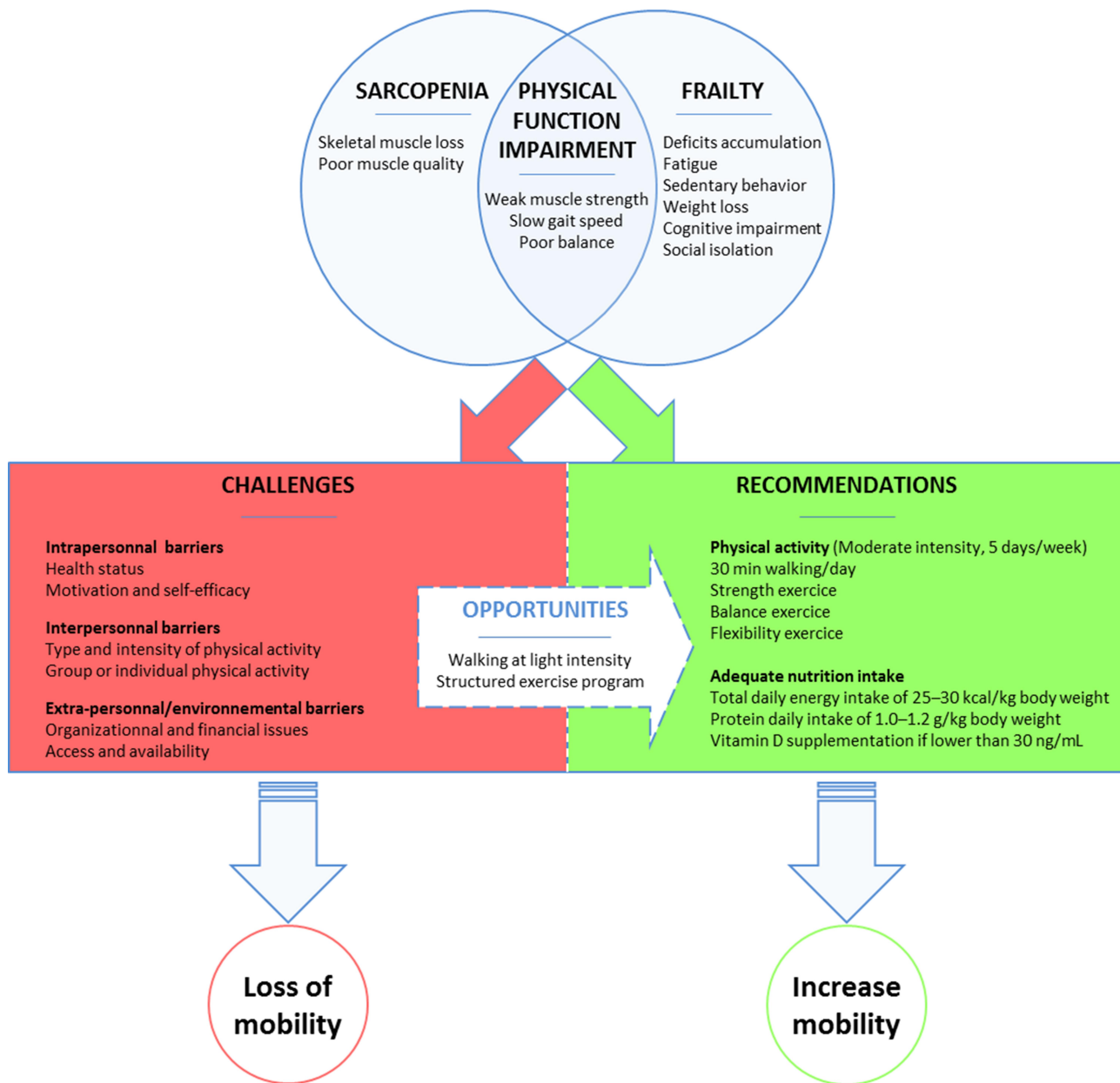
Due to current demographic trends, health promotion and physical independence are crucial. The most recent recommendations advise aging people, frail or not, to perform a minimum of 30 min of moderate intensity physical activity such as fast pace walking, at least five days per week (Figure 1).<sup>159</sup> Further, in a meta-analysis of more than one million men and women, Ekelund et al<sup>160</sup> reported that a high level of physical activity, equivalent to 60–75 min of moderate intensity per day, seemed to offset the increased mortality risk associated with prolonged sitting time. More specifically, the study found that the active older persons (about 60–75 min/day) who sit for more than eight hours daily have a significantly lower risk of mortality than people who sit for less than four hours per day with less physical activity (about five min/day). Based on these findings, physical activity can cancel out the deleterious effect of inactivity and be justified in older persons. To date, the largest and longest study on physical activity in the older population is the Lifestyle Interventions and Independence for Elders (LIFE) recently conducted in the US.<sup>12</sup> This multicenter randomized controlled trial (RCT) assessed the efficacy of a structured exercise program (designated by the authors as a physical activity program) compared to an educational group in preventing disability in 1635 sedentary and functionally

limited persons older than 70 years, over a follow-up period of 2.6 years. In the LIFE study, physical intervention was based on a combination of walking (with a goal of 150 min/week), strength, flexibility and balance exercises at the center twice per week and at home once per week (weeks 1–4), twice per week (4–8 weeks) and up to four times per week (week 8–52). The exercise sessions were individualized, setting an overall target of 30 min at moderate intensity, 10 min of strength training of lower limbs, 10 min of balance training, and flexibility exercises. This study demonstrated that compared with a health education program, a structured moderate-intensity exercise program reduced major mobility disability, persistent mobility disability and a combined outcome of major mobility disability or death over 2.6 years of follow-up.

Although no final results are available of the SPRINTT study yet, initial experiences in the challenges of recruitment in such a population have been reported<sup>161</sup> after the study protocol had been published.<sup>162</sup> The SPRINTT study, a phase III, single-blind, multicenter RCT was designed to compare the efficacy of a multicomponent intervention (MCI) program (exercise intervention, nutritional counseling/dietary intervention, and information and communication technology intervention) versus a Healthy Aging Lifestyle Education (HALE) program in prevention of mobility impairment in initially nondisabled older persons with physical frailty and sarcopenia.<sup>162</sup> Emphasizing a combination of physical activity/exercise and nutritional intervention, the SPRINTT RCT differs from the LIFE study.<sup>161</sup> The MCI program was based on the exercise protocol of the LIFE study<sup>12</sup> and consists of aerobic, strength, flexibility, and balance training.<sup>12,163</sup> The physical activity/exercise program was designed to be performed both at the center (twice a week with an instructor) and at home (3–4 times/week).<sup>125</sup> As the primary goal is to enhance mobility, strength training intervention is mainly focused on lower extremity exercises, while upper body exercises are carried out at the end of the training session.

Nutrition is a major determinant of muscle health, physical function and overall well-being, especially in older persons.<sup>164–166</sup> It follows that nutrition may play a role as a part of multicomponent interventions aimed at preserving muscle mass, counteracting physical performance decline and promoting robustness.<sup>164,167,168</sup> In this context, it is widely acknowledged that a combination of nutrition and exercise programs is one valuable approach to management of sarcopenia and the physical

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**Figure 1** A Schematic representation summarizes the opportunities, the challenges, the recommendation of physical activity intervention to preserve mobility in older adults with physical frailty and sarcopenia.

components of frailty.<sup>164</sup> Nutritional patterns conveying adequate daily energy, protein, as well as micronutrients (eg vitamins and plant-derived antioxidants), dietary fiber and healthy oils (in particular extra-virgin olive oil) have shown positive effects on muscle mass, physical function preservation and overall metabolic health.<sup>169–172</sup> Several strategies may be implemented to design a nutritional plan for older adults involved in physical activity interventions aimed at maximizing the benefits of training and overcoming the traditional

barriers that hamper its deployment in real life (ie lack of motivation, low adherence).<sup>173,174</sup>

In the SPRINTT RCT, a multifactorial approach was developed combining a physiologic/metabolic rationale with the educational/behavioral aspects of nutrition. The nutritional intervention of SPRINTT was designed to provide adequate quality and quantity of macro- and micronutrients tailored to the individual’s age, gender, health status, physical performance levels, comorbidities and therapies.<sup>162</sup> Individual preferences as well as a constant and timely

dialogue between participants and nutritional “trainers” was implemented throughout the trial to increase adherence, motivation and nutritional awareness in older persons.<sup>162</sup>

Two predefined nutritional targets were set according to expert recommendations: (1) a daily total energy intake of 25–30 kcal/kg body weight (corrected by ideal weight when appropriate); and (2) an average protein daily intake of at least 1.0–1.2 g/kg body weight.<sup>175–177</sup> Vitamin D levels were also regularly monitored and supplementation was prescribed if serum concentrations of 25-hydroxyvitamin D (25-OH-D) were below 30 ng/mL (75 nmol/L).<sup>178</sup>

## Conclusion

Aging induces biological and functional decline at several levels: loss of muscle strength, loss of muscle mass, decline in balance, and subsequent loss of mobility. Sarcopenia and more widely frailty are critical points to address in preventive physical activity/exercise programs to avoid loss of mobility and physical performance. Physical activity and nutritional support to improve physical function and to prevent sarcopenia, frailty and disability are widely recommended in the literature. While the efficacy of long-term physical activity/exercise programs is to date available only in the LIFE study conducted in the US,<sup>12</sup> the SPRINTT study will provide new evidence of physical activity program feasibility and efficacy to prevent mobility impairment among sarcopenic and physically frail older adults.

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