Are Canadian Protein and Physical Activity Guidelines Optimal for Sarcopenia Prevention in Older Adults?

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Are Canadian Protein and Physical Activity Guidelines Optimal for Sarcopenia Prevention in Older Adults?

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ABSTRACT

Aging is characterized by physiological and morphological changes that affect body composition, strength, and function ultimately leading to sarcopenia. This condition results in physical disability, falls, fractures, poor quality of life and increased health care costs. Evidence suggests that increased consumption of dietary protein and physical activity levels, especially resistance exercise, can counteract the trajectory of sarcopenia. Canadian guidelines for protein intake and physical activity were last updated in 2005 and 2011, respectively and new evidence on sarcopenia diagnosis, prevention and treatment is rapidly evolving. Protein recommendations are set as “one-size-fits-all” for both young and older adults. Recent evidence demonstrates that current recommendations are insufficient to meet the minimum protein requirement to counteract muscle loss and to stimulate hypertrophy in healthy older adults. Beyond quantity, protein quality is also essential to benefit muscle anabolism in older adults. In terms of physical activity, resistance exercise training is a potential strategy to counteract age-related effects, as it can elicit muscle hypertrophic response in addition to increases in muscle strength and function in older adults. Canadian physical activity guidelines lack details on how this modality of training should be performed. Current guidelines for protein intake and physical activity do not reflect recent knowledge on sarcopenia prevention. The gap between guidelines and the latest evidence on the maintenance and promotion of older adult’s health highlight the need for updated protein and physical activity recommendations.

Key words: Physical activity, protein intake, guidelines, elderly, sarcopenia.

INTRODUCTION

Aging is accompanied by a progressive decline in skeletal muscle mass quantity and quality, which negatively impact individuals' body composition, muscle strength, and physical function, leading to clinical problems (Miljkovic et al. 2015). Sarcopenia has been defined as the age-related progressive and generalized loss of skeletal muscle mass, strength, and physical function (Rosenberg 1997; Cruz-Jentoft et al. 2010), affecting 5 to 13% and 11 to 50% of older adults aged 60 to 70 years and above 80 years of age, respectively (von Haehling et al. 2010; Shafiee et al. 2017).

As muscle mass and strength are essential for mobility and vitality, sarcopenia is associated with physical disability, falls, fractures, frailty, poor quality of life (Visser and Schaap 2011; Beudart et al. 2014) and increased health care costs (Beudart et al. 2014). Despite the prevalence of this condition and its impact on population's health status and quality of life, sarcopenia was only acknowledged as a disease in 2016, when the World Health Organization (WHO) released an International Classification of Diseases for sarcopenia [10th revision, Clinical Modification (ICD-10-CM) code (M62.84)]. This recognition increases awareness and attention, providing the basis for resource allocation with potential to influence public health and health policy (The Aging in Motion Coalition 2018). Therefore, strategies aimed at preventing sarcopenia are of high importance and need to be incorporated on a public health level to improve population's quality of life and reduce its socio-economic impact.

Nutrition and physical activity are essential in the prevention of sarcopenia. A growing body of literature recognizes the importance of proper nutrition, especially protein intake, and physical activity to attenuate age-related effects on skeletal muscle (Beudart et al. 2017; Naseeb

and Volpe 2017). Canadian guidelines for protein intake (Institute of Medicine 2005) and physical activity (Canadian Society for Exercise Physiology 2011) for older adults were developed to maintain and promote health, as well as to prevent chronic diseases, which includes sarcopenia. However, these recommendations do not reflect recent evidence, highlighting the need for updated, evidence-based guidelines. The aim of this narrative review was to describe the latest evidence on protein intake and physical activity for the prevention of sarcopenia and to compare with current Canadian guidelines, identifying gaps and opportunities for future recommendations targeting this important condition.

EFFECTS OF AGING ON SKELETAL MUSCLE

Aging is a complex biological process characterized by physiological and morphological changes that affect muscle mass and strength (Rolland et al. 2008; Miljkovic et al. 2015), which in turn impact older adults' morbidity and mortality (Ruiz et al. 2008; Puthuchearry and Hart 2014). Changes in skeletal muscle mass and strength with aging are essentially a result of a progressive decline in size and number of motor units and muscle fibers, especially type II, along with contractile quality and neural activation impairments (Porter et al. 1995; Hughes et al. 2001), which may result in sarcopenia (Cruz-Jentoft et al. 2010).

Sarcopenia etiology involves multiple mechanisms (Lang et al. 2010; Walrand et al. 2011). Among them, an early stage of resistance to anabolic stimuli (Haran et al. 2012; Burd et al. 2013) along with inadequate nutrient intake (Martone et al. 2013; Morley 2017) and sedentarism (Marzetti et al. 2017) contribute to its onset and progression (**Figure 1**). Although age-related changes decrease older adults' muscle protein synthesis (MPS) response to dietary

protein and physical activity, higher protein consumption and increased physical activity levels can attenuate it (Kumar et al. 2009; Moore et al. 2015). Therefore, it is evident that nutrient intake recommendations, especially protein, and physical activity should be age-specific due to different response to anabolic stimuli. Moreover, recent evidence should be taken into consideration when designing guidelines for this population using new methodological approaches and considering contemporary cohorts of elderly individuals.

PREVENTING SARCOPENIA WITH CANADIAN GUIDELINES – GAPS & OPPORTUNITIES

Dietary Protein Recommendations

Current Canadian dietary protein recommendations are based on Dietary Reference Intakes (DRIs) (Institute of Medicine 2005), not specific for older adults. These recommendations are defined as both absolute and relative amounts, as Recommended Dietary Allowance (RDA) and Acceptable Macronutrient Distribution Range (AMDR), respectively (Institute of Medicine 2005). Protein RDA was last established as 0.80 g/kg body weight (BW)/day for younger (19 to 50 years) and older adults (51 years and older) of both sexes, a value that should theoretically meet requirements of 97 to 98% of these population groups (Rand et al. 2003; Institute of Medicine 2005).

Protein Estimated Average Requirement (EAR) and RDA values were estimated based on nitrogen-balance studies; however, this technique is no longer recommended due to inherent problems associated with its methodology, analysis/interpretation, as well as the availability of

new techniques involving carbon oxidation measured using stable isotopes (i.e. indicator amino acid oxidation – IAAO; 24h-indicator amino acid oxidation and balance method - 24h-IAAO/IAAB) (Zello et al. 1995; Humayun et al. 2007; Elango et al. 2012). New evidence indicates the EAR and RDA for protein intake should be 0.91 g/kg BW/day and 1.0 g/kg BW/day for healthy adults, respectively (Humayun et al. 2007; Elango et al. 2010). Moreover, the IAAO method revealed protein needs in healthy adults to be 41% and 50% higher than current EAR (0.93 g/kg BW/day) and RDA (1.2 g/kg BW/day), respectively (Humayun et al. 2007; Elango et al. 2010).

In spite of limitations related to the use of nitrogen balance studies, current guidelines follow the “one-size-fits-all” protein recommendation for men and women, young and older adults (Institute of Medicine 2005). The meta-analysis of nitrogen balance studies used to determine protein requirements only included one study with 14 older adults (n=7 of each sex) in the analysis (Uauy et al. 1978; Rand et al. 2003). Data with older adults showed a median nitrogen requirement of 131 mg of nitrogen/kg BW/day (0.82 g of protein/kg BW/day), a value 26% higher than that estimated for younger adults (104 mg of nitrogen/kg BW/day = 0.65 g of protein/kg BW/day); however, this difference was not statistically significant (Rand et al. 2003). This data also demonstrated that older adults had lower efficiency of nitrogen utilization for retention when compared to young adults (31% and 48%, respectively) (Rand et al. 2003). Although these are intriguing results, insufficient data with older adults precludes conclusions on whether their protein needs is different, and therefore hindered age-specific recommendations (Rand et al. 2003).

Older adults’ protein requirements were recently reassessed using the IAAO method. Estimated Average Requirement and RDA were estimated to be 0.94 and 1.24 g/kg BW/day of

older men (>65 y) (Rafii et al. 2016), and 0.96 and 1.29 g/kg BW/day of older women (>65 y) (Rafii et al. 2015), respectively. When assessing octogenarian women's requirements, the IAAO method revealed EAR to be 0.85 g/kg BW/day and RDA 1.15 g/kg BW/day (Tang et al. 2014). Although these values were not so divergent from the IAAO analysis in younger adults, a population-based study (N=2066 community-dwelling individuals aged 70 to 79 years) showed that those consuming 1.2 g of protein/kg BW/day lost lean mass over a 3-year follow-up; however, the loss was 40% lower compared to those consuming 0.8 g of protein/kg BW/day (Houston et al. 2008). This result is supported by data from ten healthy ambulatory individuals (55 to 77 years) showing that protein fed at RDA levels for 14 weeks resulted in a decrease of $1.7 \pm 0.6 \text{ cm}^2$ of mid-tight muscle area (Campbell et al. 2001). Although the IAAO method demonstrated that ~1.2 to 1.3 g/kg BW/day of protein is needed to achieve a state of nitrogen balance in older adults, longer term studies are needed to confirm whether these values are sufficient to avoid metabolic and physiological accommodation in older adults.

As showed above, based on the IAAO method, the estimated RDA for protein is lower in older men (i.e. 1.24 g/kg BW/day) compared to older women (i.e. 1.29 g/kg BW/day) (Rafii et al. 2015; Rafii et al. 2016). These findings are supported by a study assessing sex differences on MPS rate in older adults (n=20, 65 to 85 years) (Smith et al. 2012a). Basal rate of MPS was ~30% higher in women compared to men, confirming sex-differences in muscle protein turnover with aging (Smith et al. 2012a), suggesting the importance of individualized protein recommendations by sex.

Although defined as the minimum daily average intake level of a certain nutrient, RDA terminology may be misinterpreted as "recommended" or "allowed" level of intake, therefore, the term "*minimal daily requirement*" has been proposed instead (Wolfe and Miller 2008).

However, minimal and optimal levels of protein intake might not have distinct concepts, as both are aimed to maintain health status and prevent the development of diseases. Therefore, protein recommendations should be specific for distinct population groups (i.e. age, sex, health status, and physical activity levels) and not based on minimal or optimal levels of intake, as these are distinct for each of these groups. Protein recommendations based on these characteristics are not yet completely defined and research is ongoing. Moreover, the Grading of Recommendations Assessment, Development and Evaluation (GRADE) evidence assessment algorithm should be used to indicate the strength of the recommendation. Work on this area is advancing with new research opportunities that would help the development of future DRIs based on such endpoints (Yetley et al. 2017).

Besides RDA values, protein requirements are also established as AMDR which is expressed as wide range of (10 to 35%) of total energy intake (Institute of Medicine 2005), with no specific value by sex or age group. Using the DRIs predictive equations to estimate individual's energy needs, protein requirements based on the AMDR range can be below or well above the RDA (**Figure 2**) (Institute of Medicine 2005). The discrepancy between these reference values gets even larger when comparing men and women with similar characteristics (**Figure 2**). Although the AMDR is a flexible value created to accommodate individual's characteristics, the range is excessively wide and confusing when the RDA is also used to plan nutrient intake.

In addition to protein intake recommendations in both absolute and relative amounts, the DRIs suggest high-quality protein sources should be consumed to meet growth, maintenance and repair requirements. Protein quality is determined mainly by its digestibility and amino acid composition, with complete and incomplete proteins briefly characterized by the presence or

absence of the nine indispensable amino acids (IAA) (Institute of Medicine 2005). Additionally, examples of complete and incomplete protein sources are given. Although the protein digestibility corrected amino acid score (PDCAAS) was originally recommended to evaluate protein quality in humans, the digestible indispensable amino acid score (DIAAS) has been recommended since 2013 (Food and Agriculture Organization of the United Nations 2013). This method is based on each amino acid ileal digestibility, which more accurately reflects the quality of protein sources. A summary of key opportunities for improving Canadian dietary protein guidelines can be found in **Table 1**.

Canadian Physical Activity Guidelines

Canadian physical activity recommendations are based on the Canadian Physical Activity Guidelines (Tremblay et al. 2011), which includes a designated older adult section (Canadian Society for Exercise Physiology 2011). The guidelines have been developed by the Canadian Society for Exercise Physiology since 1995 in collaboration with the Public Health Agency of Canada, with the goal of improving lifestyle and therefore health status. The 2011 Canadian Physical Activity Guidelines for Older Adults recommended a minimum of 150 minutes of moderate- to vigorous-intensity aerobic physical activity per week, divided in bouts of 10 minutes or more to achieve health benefits and improve functional abilities. The inclusion of muscle and bone strengthening activities at least twice a week was also recommended. Individuals with limited mobility were instructed to perform physical activities to enhance balance and prevent falls. Lastly, the document pointed out that health benefits increased with increased amounts of physical activity (Canadian Society for Exercise Physiology 2011).

According to the Canadian Health Measures Survey, only 12% of older adults meet the recommended amount of physical activity established by the Canadian Physical Activity Guidelines for Older Adults (Statistics Canada 2015). Unfortunately, a limited number of Canadians are aware of the guidelines existence (i.e. 12.9% of the adult population) (Dale et al. 2016). Somehow, dissemination of the guidelines was not as efficient as initially proposed, reinforcing the need for improved marketing and communication strategies (Tremblay et al. 2011; Dale et al. 2016).

Current Canadian Physical Activity Guidelines for Older Adults focus primarily on aerobic activity, discussing its frequency and intensity (Canadian Society for Exercise Physiology 2011). With reference to resistance exercise training (RET), the document only mentions that muscle and bone strengthening activities using major muscle groups should be conducted at least twice a week with no further details or explanation on how this modality of training should be performed. It is known that RET is associated with multiple health benefits in older adults, more specifically on muscle mass, strength, and physical function improvements (Liu and Latham 2009; Peterson et al. 2010; Peterson et al. 2011). Therefore, an emphasis on the importance of RET and its implementation, especially among older adults, is needed.

Approximately 10% of American older adults engage in leisure time RET (Centers for Disease Control and Prevention 2008). Although Canadian data is lacking, the numbers may be comparable. Therefore, strategies able to increase involvement and adherence to RET are needed. It may be beneficial to incorporate uncomplicated RET or to provide specific guidelines on this type of training. Uncomplicated RET has been proposed as an attractive approach, in which a brief, simple and feasible population-level training protocol performed twice weekly is recommended (Phillips and Winett 2010). An alternative strategy would be to provide specific

guidelines on which type, how often, and how much resistance exercise should be performed (i.e. load, number of sets, repetitions per set, and interval between sets). Moreover, information on training progression should be given as a maximum number of repetitions of the same movement; and intensity increments should be advised by providing cues such as “*If you can perform more than X repetitions in a row, add some resistance or weight*”. Although both approaches are interesting concepts, further research is needed to elucidate their impact on older adults’ involvement, adherence and health outcomes.

With the objective of improving our guidelines, observational studies can identify the type and duration of physical activity performed by this population group. However, considering the low prevalence of older adults meeting the recommended amount of physical activity (Statistics Canada 2015) and engaging in RET (Centers for Disease Control and Prevention 2008), it is also important to understand the context in which it occurs so that better approaches are developed, increasing participation rates. Social and environmental aspects involved in physical activity performance vary considerably. Evidence suggests older adults prefer to exercise with people of similar age, and at a flexible schedule (Burton et al. 2012). Additionally, vigorous and team-based activities are not appreciated by this population group. Olanrewaju et al. (2016) suggested that providing more information on the benefits of physical activity, affordability, and environmental safety would encourage physical activity behaviour. Local community assets, such as walk-trails, green space, group activities and social networks would also be of benefit (Lacharite-Lemieux et al. 2015; Olanrewaju et al. 2016). Therefore, guideline-specific information on the context in which physical activity should occur may increase participation rates, as this would help older adults explore new individualized

strategies/opportunities. A summary of key opportunities for improving Canadian physical activity guidelines can be found in **Table 2**.

LATEST EVIDENCE ON SARCOPENIA PREVENTION

Considering the evolving understanding of the relationship between sarcopenia and protein intake or physical activity, it is reasonable to infer that guidelines developed approximately a decade ago or longer may not depict the latest scientific evidence. The following section describes the current knowledge on protein intake and physical activity as it relates to sarcopenia prevention.

Dietary Protein

Data from several observational and experimental studies gathered in recent review papers have demonstrated that current protein RDA is insufficient to meet minimum requirements to counteract skeletal muscle loss with aging and promote hypertrophy of this body compartment in healthy older adults (Bauer et al. 2013; Deutz et al. 2014; Phillips 2017a). Therefore, current protein recommendations for older adults is not sufficient to prevent sarcopenia, which precludes DRI's objective of maintaining and promoting health, as well as preventing chronic diseases (Institute of Medicine 2005). Beyond quantity, evolving evidence indicates that protein quality and distribution of intake throughout the day are also essential to promote skeletal muscle growth in older adults (Naseeb and Volpe 2017; Phillips 2017a; Wolfe

et al. 2017), which is not covered in the guidelines. The next two sub-sections discuss recent evidence on protein quantity, quality, and distribution of intake on sarcopenia prevention.

Quantity

Healthy older adults need a higher protein intake due to physiological anorexia, decreased protein and energy intakes, weight loss and metabolic inefficiency (Morley et al. 2010). Altogether, these factors may lead to a decline in muscle mass and increased mortality, which has been argued to be prevented and managed by an intake of 1.0 to 1.5 g protein /kg BW/day (Morley et al. 2010). Furthermore, supplementation with a leucine-enriched balanced essential amino acid mix was recommended to slow muscle loss (Morley et al. 2010).

More recently, an international expert panel (PROT-AGE Study Group) criticized the “one-size-fits-all” RDA for protein intake for healthy and diseased older adults, affirming their need for higher protein intake (compared to younger adults) to maintain good health and functionality (Bauer et al. 2013). Their protein intake recommendation was between 1.0 and 1.2 g/kg BW/day to help maintain and regain muscle mass without affecting renal function. If engaged in exercise, the recommended amount would increase to 1.2 to 1.5 grams of protein/kg BW/day. Moreover, the consumption of 25 to 30 grams of protein per meal containing about 2.5 to 2.8 grams of leucine was encouraged (Bauer et al. 2013).

A year after the PROT-AGE Study Group review was published, the European Society for Clinical Nutrition and Metabolism (ESPEN) developed protein intake recommendations to maintain muscle health and physical function in older adults (Deutz et al. 2014). This article included the latest evidence presented on a workshop hosted by and composed of the ‘Protein Requirements in the Elderly’ ESPEN Expert Group. Protein recommendations were suggested

based on the presence or absence of chronic or acute illnesses. For healthy older adults, a minimum of 1.0 to 1.2 grams of protein/kg BW/day was recommended. Although protein source, pattern of intake and specific amino acids and metabolites were topics discussed in the paper, the authors noted more evidence was needed to draw conclusions/recommendations (Deutz et al. 2014).

More recently, several scientists, health experts, and nutrition educators gathered to discuss protein intake recommendation and its role in human health and sarcopenia prevention (Rodriguez 2015). Proceedings of this event, called *Protein Summit 2.0*, were published as five articles, one of which discussing protein intake on healthy aging (Paddon-Jones et al. 2015). The recommendation for preventing the onset/slowing the progression of sarcopenia in healthy older adults was of 1.0 to 1.5 grams of high-quality protein/kg BW/day consumed and evenly distributed throughout the day (meeting a threshold of ~25 to 30 grams of protein per meal) (Paddon-Jones et al. 2015).

Several recent reviews have also criticized current protein recommendation for older adults and proposed adjustments for sarcopenia prevention (Paddon-Jones et al. 2008; Wolfe et al. 2008; Gaffney-Stomberg et al. 2009; Paddon-Jones and Leidy 2014; Deer and Volpi 2015; Nowson and O'Connell 2015; Baum et al. 2016; Courtney-Martin et al. 2016; Landi et al. 2016; Murphy et al. 2016; Phillips et al. 2016; Shad et al. 2016; Naseeb and Volpe 2017; Phillips 2017a). A summary of protein intake recommendation for healthy older adults proposed by recent review articles is shown in supplementary **Table S1**¹.

Quality & Distribution of Intake

¹ Supplementary Table S1.

Protein quality as well as distribution of intake throughout the day can influence MPS (Paddon-Jones and Leidy 2014; Murphy et al. 2016). The ability of protein sources to influence MPS depends mainly on its IAAs content, especially the presence of leucine, which gives protein from animal sources an advantage compared to plant sources (supplementary **Table S2**²) (Volpi et al. 2003; Katsanos et al. 2006). Apart from its role as a simple building block during MPS, leucine is a potent insulin secretagogue and acts as a signaling molecule activating the mechanistic target of rapamycin (mTOR) pathway in an insulin-dependent and independent manner (Drummond and Rasmussen 2008). Studies have shown that a minimum of 55 mg of leucine/kg BW/day or ≥ 2.5 grams per meal is able to increase postprandial MPS in healthy older adults (Leenders and van Loon 2011; Borack and Volpi 2016). Although leucine consumption appears to be safe in older adults, its intake should not exceed 351 mg/kg BW/day (Elango et al. 2016).

Evidence suggests older adults' usual protein intake is not equally distributed throughout the day (supplementary **Figure S1**³) as a higher protein intake is observed during dinner (U.S. Department of Agriculture et al. 2013-2014). This uneven pattern of intake has been criticized as older adults' MPS has been shown to be stimulated by higher doses of IAA (i.e. 10 to 15 grams) (Paddon-Jones et al. 2004; Katsanos et al. 2005), meaning intakes below these amounts are suboptimal for MPS stimulation. Even when protein is equally distributed throughout daily meals, the amount of nutrient per meal needs to be sufficient to stimulate MPS; otherwise, muscle mass and function will not be positively affected (Arnal et al. 1999; Bouillanne et al. 2013). Therefore, a threshold of 25 to 30 grams of high-quality protein (i.e. ~ 10 grams of IAA) or 0.4 g/kg BW/meal has been proposed as a strategy to improve MPS in healthy older adults

² Supplementary Table S2.

³ Supplementary Figure S1.

(Murphy et al. 2016; Phillips 2017b). Although few observational studies highlighted the impact of evenly distributed protein intakes (Farsijani et al. 2016; Farsijani et al. 2017), these findings were not supported by acute and short-term randomized controlled trials (Kim et al. 2015; Kim et al. 2018), precluding its recommendation to healthy older adults.

Physical Activity

Resistance exercise training gained attention as a strategy to counteract age-related loss of muscle mass, strength and performance (Brown et al. 1990). Interestingly, although the mechanical and metabolic processes involved with muscle mass, strength and physical function improvement are not similar, RET can impact all these factors (American College of Sports Medicine 2009), making it a unique approach to prevent the age-related decline in physical function. Therefore, RET is crucial on the prevention of sarcopenia (Law et al. 2016; Ziaaldini et al. 2017).

Several studies assessing the effects of RET on older adults have been summarized in recent systematic reviews and meta-analysis (Liu and Latham 2009; Peterson et al. 2010; Liu and Latham 2011; Peterson et al. 2011; Valenzuela 2012; Raymond et al. 2013; Silva et al. 2014; Van Abbema et al. 2015; Law et al. 2016; Straight et al. 2016; Buch et al. 2017; Papa et al. 2017). The largest recently conducted meta-analysis on the effects of progressive RET on older adults' physical function included 121 trials and 6,700 individuals >60 years (Liu and Latham 2009). Training programs were fully supervised in all studies and were of moderate to high intensity with a minimum frequency of two to three times per week in the majority of the included trials (Liu and Latham 2009). The authors concluded that progressive RET can improve

older adults' physical function, functional limitations and strength. Moreover, when compared to aerobic training, RET elicited larger gains in strength and equivalent improvements in aerobic capacity and physical disability, giving an advantage to RET on sarcopenia prevention in healthy older adults. A minimum of two to three times per week of progressive RET was suggested to improve physical function and reduce physical disability, functional limitations and muscle weakness in older adults (Liu and Latham 2009). In addition to progressive RET, a recent study demonstrated that other modalities can also improve older adults' physical fitness and function (Allen et al. 2017). Participants >70 years at risk for losing functional independence performed either a low mass, high repetition/duration skeletal muscle focused training regimen (i.e. peripheral remodeling through intermittent muscular exercise - PRIME) or standard aerobic exercise training for four weeks, followed by eight weeks of progressive whole-body aerobic and RET. Compared to standard aerobic exercise training, greater improvements in physical fitness and function were observed with the PRIME approach (Allen et al. 2017). These results highlight the importance of incorporating this modality of training in population groups with low cardiorespiratory fitness and reduced physical function, such as older adults and individuals diagnosed with sarcopenia (Allen et al. 2017). Moreover, the PRIME approach can be incorporated in settings other than gyms (e.g. home, public parks, community facilities, etc.) using alternative equipment (e.g. elastic bands, exercise balls, etc.), which might favour older adults' involvement and adherence to RET.

Although RET is known to influence strength, specific variables related to this outcome have rarely been individually analysed. Peterson et al. (2010) conducted a meta-analysis assessing the effects of RET on older adults' upper- and lower-body strength outcomes. Forty-seven trials including 1079 individuals ≥ 50 years of age training 2.7 ± 0.5 days/week at $70\% \pm 12.7$

of their 1 repetition maximum (1RM) were included in the analysis (Peterson et al. 2010). In spite of study heterogeneity, mean strength change in leg press, chest press, knee extension and lateral pull from baseline to post-intervention was significant ($p < 0.001$, supplementary **Figure S2**⁴). Furthermore, higher intensity RET elicited greater improvements in strength (Peterson et al. 2010). Both meta-analysis described above showed strong evidence that RET can increase older adults' skeletal muscle strength (Liu and Latham 2009; Peterson et al. 2010). In order to clarify if this improvement could be translated into better physical function and hence quality of life, Liu and Latham (2011) conducted a meta-analysis involving 2,172 individuals >60 years participating in RET two to three times per week. This modality of training had a positive impact on reducing physical disability in older adults suggesting this population group should undergo progressive RET two to three times per week, with training starting at low intensity and progressing gradually until moderate to high intensity is achieved. After the target intensity is reached, a minimum of six weeks is required for noticeable benefits (Liu and Latham 2011). These findings/recommendations were further explored and confirmed by additional recent systematic reviews and meta-analyzes (Valenzuela 2012; Raymond et al. 2013; Silva et al. 2014; Van Abbema et al. 2015; Straight et al. 2016; Papa et al. 2017).

Resistance exercise training has been proposed as a strategy not only to counteract the consequences of muscle loss, but also to increase muscle mass, as demonstrated by a meta-analysis including 1,328 adults ≥ 50 years (Peterson et al. 2011). Compared to baseline, post-intervention body composition analysis showed that older adults increased their lean mass by 1.1 kg (95% CI = 0.9–1.2 kg; $p < 0.001$). Additionally, the volume of training was directly proportional to the change in lean mass ($\beta = 0.05$, $p < 0.01$); and as age increased, lean mass gain decreased ($\beta = -0.03$, $p = 0.01$) (Peterson et al. 2011).

⁴ Supplementary Figure S2.

Individuals' response to RET benefits is highly variable. While some individuals demonstrate several benefits upon starting this type of training (Davidsen et al. 2011; Stewart et al. 2014), others may not demonstrate a fast and apparent response (Hubal et al. 2005). Different responses to RET may imply there are responders and non-responders. By retrospectively analysing the adaptive response of 110 and 85 older adults (>65 years) undergoing 12 and 24 weeks of RET, respectively, the authors demonstrated a variable, yet positive response to RET stimuli (Churchward-Venne et al. 2015). Although there were no non-responders, evidence suggests that older women and men might react differently to the anabolic stimuli generated by RET (Bamman et al. 2003; Greig et al. 2011; Smith et al. 2012b; Da Boit et al. 2016). The most recent long-term study assessing how sex impacted older adults' response to RET involved 18 weeks of supervised RET in 13 men and 10 women (>65 years) (Da Boit et al. 2016). At the end of the intervention, knee extensor muscle strength and muscle quality (i.e. force per unit anatomical cross-sectional area) were greater in older men compared to older women. Although the mechanisms related to these observations were not explored, the authors suggested that older adults might require sex-specific resistance exercise strategies (Da Boit et al. 2016).

As discussed above, RET positively impacts older adults' muscle mass, strength and physical function. Therefore, it is crucial to improve their involvement and adherence to this type of training for sarcopenia prevention. The majority of studies demonstrated positive results with exercise performed as full-body, progressive RET of moderate to high intensity, two to three times per week. Other characteristics, such as the amount of exercise, sets, repetitions and interval between sets were highly variable among studies. In addition, studies have demonstrated that performing RET in other facilities than gyms using a wide range of equipment are also

effective. Therefore, these options should also be considered and specified when prescribing RET to older adults.

CONCLUSION

Evidence suggests that increased consumption of dietary protein and physical activity levels, specially RET, can counteract sarcopenia. Recent evidence demonstrates that current recommendations are insufficient to meet the minimum protein requirement to counteract skeletal muscle loss and to stimulate hypertrophy in healthy older adults. Beyond quantity, protein quality is also essential to benefit muscle anabolism. In terms of physical activity, Canadian guidelines focus primarily on aerobic physical activity and, although RET recommendation is mentioned, no details or explanation on how this modality of training should be performed is provided. Current guidelines for protein intake and physical activity do not reflect recent knowledge on the topic. Considering the gap between the guidelines and the latest evidence on the sarcopenia prevention, updated recommendations are needed.

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Draft

775 **Table 1.** Key opportunities for improving Canadian dietary protein guidelines for older adults

Further long-term, controlled trials using the IAAO [*] technique are needed to assess older adults' protein requirements; moreover, strength, physical function, body composition, and health outcomes should also be assessed. These trials should be conducted considering potential sex differences in protein requirements;
Dietary protein recommendations should be specific for distinct population groups (i.e. age, sex, health status, and physical activity levels) and not based on minimal or optimal levels of intake;
Dietary guidelines should use the GRADE [†] evidence assessment algorithm to indicate the strength of the recommendation;
Dietary guidelines should provide the definition and examples of high-quality protein sources using the DIAAS [‡] .

776 ^{*}IAAO: Indicator Amino Acid Oxidation.

777 [†]GRADE: Grading of Recommendations Assessment, Development and Evaluation.

778 [‡]DIAAS: Digestible Indispensable Amino Acid Score.

779 **Table 2.** Key opportunities for improving Canadian physical activity guidelines for older adults

Canadian Physical Activity Guidelines should be better disseminated;
Guidelines for older adults should emphasize the importance of RET* and how it should be implemented;
Guidelines should provide detailed information on which RET* should be performed, how often, how much, and how to progress as a strategy to increase involvement and adherence;
Information on the context in which physical activity should occur should be added to the guidelines as it may increase participation rates and would help older adults explore new individualized strategies.

780 *RET: Resistance exercise training.

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Figure 1. Main causes of anabolic resistance and anorexia of aging contributing to the onset and progression of sarcopenia.

Rolland et al. 2008; Walrand et al. 2011; Haran et al. 2012; Burd et al. 2013; Martone et al. 2013; Landi et al. 2016; Morley 2017.

Figure 2. Estimated energy and protein requirements for older adults with the same age, height, weight and BMI. Based on AMDR's range, protein requirements are below or well above RDA (i.e. 0.8 grams of protein per kg of body weight per day). Abbreviations: AMDR: acceptable macronutrient distribution range; BMI: body mass index; EER: estimated energy requirements; g/kg/day: grams of protein per kg of body weight per day; RDA: recommended dietary allowance.

Institute of Medicine 2005.

Individual A

Sex: Male

Age: 70 years old

Height: 1.78 m

Weight: 70 kg

BMI: 22 kg/m²

EER: 2070 kcal/day

Protein requirements (10% of EER): 0.73 g/kg/day

Protein requirements (35% of EER): 2.58 g/kg/day

Individual B

Sex: Female

Age: 70 years old

Height: 1.78 m

Weight: 70 kg

BMI: 22 kg/m²

EER: 1817 kcal/day

Protein requirements (10% of EER): 0.64 g/kg/day

Protein requirements (35% of EER): 2.27 g/kg/day