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Powerpenia: should it be considered a biomarker of healthy aging?

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ABSTRACT

To identify biomarkers that precede the human function decline and independence during lifespan, two important concepts have been introduced in the last decades: sarcopenia and dynapenia. While the former is originally focused on skeletal muscle loss, the latter is on maximal strength loss. Although the dynapenia concept foresees the inclusion of skeletal muscle power, in practical terms, this has not been specifically addressed. For instance, only 2 out of 220 studies published between 2008 and 2023 have directly measured muscle power to classify individuals with dynapenia. As previous studies have shown a greater relevance of skeletal muscle power in healthy aging, we hereby propose the introduction of the term named "powerpenia" to specifically reflect the loss of skeletal muscle power along lifespan. Together with sarcopenia and dynapenia, we contend that powerpenia should be considered a biomarker of healthy aging.

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Authors SRF @sandro10freitas, CCM @HumanMov and SR @ratel_sebastien can be reached on X (ex-Twitter). Key-words: dynapenia, health, neuromuscular function, quality of life, sarcopenia, sedentarism.

Key points:

- Skeletal muscle power has been reported to have greater influence on physical function and falls
 reduction in older adults compared to muscle strength, and a more sensitive marker in the
 presence of disease and/or physical inactivity than muscle strength and mass.
- Dynapenia concept has been focused on skeletal muscle maximal strength rather than power.
- We propose the introduction of the term powerpenia to specifically address the loss of skeletal muscle power with aging, disease, and/or physical inactivity.

1. Introduction

In normal circumstances, humans seek to be physically independent in their daily living to safeguard their quality of life. However, humans are becoming increasingly sedentary in all stages of life, and this negatively impacts the human skeletal muscle force-velocity properties, functional abilities, quality of life, and longevity [1–3]. Researchers and reputable advisory institutions worldwide (e.g. the World Health Organization) are now interested in promoting healthy living with a particular interest in attenuating the decline in human function where physical exercise plays a key role.

Over the last four decades, two main biomarkers have been introduced to identify the early decline in human physical function in the later stages of life: sarcopenia and dynapenia. In 1988, Irwin H. Rosenberg proposed two terms to reflect the concept of skeletal muscle mass loss with age, specifically sarcomalacia and sarcopenia [4]. The latter term has prevailed in the community worldwide and it has been considered a fundamental criterion of human health in different stages of life and in a range of clinical conditions [5]. In 2008, Brian C. Clark and Todd M. Manini proposed the concept of dynapenia to specifically focus on the loss of skeletal muscle strength and power due to its potentially greater relevance when explaining human function decline and due to the poor association with muscle mass loss [6]. Some years later [7,8], a consensual review of the sarcopenia concept introduced the criteria of muscle function (i.e., maximal strength production capacity used for handgrip and walking locomotion). Notably, skeletal muscle power (see definition further) has not been included in both the original and revised sarcopenia definitions [4,7,9]. However, in practical terms, sarcopenia has been focused on a loss of skeletal muscle mass rather than function [10]. Thus, some researchers are currently of the opinion that sarcopenia should focus on its original concept [11].

Over the years, a considerable number of studies have differentiated the concepts of dynapenia and sarcopenia due to three main reasons. Firstly, the onset of skeletal muscle strength loss with age is likely to occur before the onset of muscle mass loss [9,12]. Secondly, the decrease rate is higher for muscle

strength compared to mass [9,13]. Thirdly, strength loss related to aging cannot be explained entirely by a decrease in muscle size [14]. As such, the application of terms that fit the meaning of the original concepts is justified, considering how sarco- means "muscle" [4], dyna- refers to "power, strength, or force" [6], and penia- means "poverty". It should be noted that the use of the conjunction "or" between strength and power in the dynapenia original concept suggests that these functional parameters are equivalent. However, this is not the case. Human strength is defined as the force a muscle can produce to overcome a resistance while power is defined as the amount of work performed per unit of time, which can be determined by the product of muscle force and velocity [15,16]. For instance, individuals may have similar strength capacities but with different power outcomes. As such, the assessment of both parameters requires different approaches. The rate of power loss during aging is also higher than strength [17]; and thus the power loss with age cannot be fully explained by loss of strength [3]. The relevance of these functional parameters during aging are also not similar, as higher association to human physical function and falls reduction has been observed to skeletal muscle power rather than strength [2]. The distinction between strength and power is also required because there are specific factors that regulate a fast voluntary muscle action [18], even if the other factors underpinning the production of both maximal strength and power are similar. This means that to classify individuals with dynapenia according to the original concept, there would have to exist a criterion regulated simultaneously by both parameters. However, this is not the case, as the criteria to diagnose dynapenia has mainly been assessed based on maximal strength. As shown in Table 1, among the works published between 2008 and 2023 who objectively classified individuals as having dynapenia (n=220, see list in supplementary file_1), only two studies (i.e. 0.9%) used an objective measure of muscle power. Most studies (i.e. 91.8%) assessed dynapenia through the quantification of hand grip maximal strength. This discrepancy calls for the need to differentiate loss of muscle strength and loss of muscle power within the dynapenia concept, or to redefine the concept. Interestingly, in 2011, Morley et al. proposed the term kratopenia to characterize the "loss of force" and dynapenia to characterize the "loss of power" [19], although there was no subsequent adhesion to this proposal. However, a clear differentiation between strength and power is warranted.

Type of test to diagnose dynapenia	n (%)	%
Handgrip	170	77.3%
Handgrip and 6-m walk	20	9.1%
Handgrip and isometric leg extension	5	2.3%
Isometric leg extension	4	1.8%
Isokinetic leg extension	4	1.8%
Handgrip and sit to stand	4	1.8%
Sit to stand	2	0.9%
Mid-thigh pull	2	0.9%
Sit to stand power	1	0.5%
Phase angle (BIA)	1	0.5%
Leg press and bench press	1	0.5%
Isometric leg extension strength and power	1	0.5%
Handgrip, 6-m walk and Timed Up and Go	1	0.5%
Handgrip and Short Physical Performance Battery	1	0.5%
Handgrip and inverted grid-hang test	1	0.5%
Eccentric strength of the hip-flexors and hip abductors	1	0.5%
Bench press and knee extension	1	0.5%
Inclusion of specific power measures?	n	%
Yes	2	0.9%
No	218	99.1%

Table 1. Type of tests used to assess dynapenia in humans, reported in studies published between 2008

 and 2023 (n=220, until August 7th) searched in the Pubmed search engine with the word "dynapenia".

2. Powerpenia

We hereby introduce the term *powerpenia* to specifically address the loss of skeletal muscle power induced by aging, clinical conditions, and/or physical inactivity. Consequently, we suggest that dynapenia should be focused only on skeletal muscle maximal strength. The need to identify a specific term that addresses the loss of skeletal muscle power with age has also been raised recently [20]. Notably, the term powerpenia has not been used before in the literature. We admit that the use of prefix powerwill intuitively lead individuals to the meaning of the concept. The term power has only been considered as a medical subject heading in Pubmed from a psychological dimension, suggesting that skeletal muscle power is not a topic considered in biomedical and health-related contexts, contrary to muscle strength (but not dynapenia) and sarcopenia. We contend that introducing the powerpenia concept will help to distinguish between muscle strength and power and intuitively convey the power decline due to aging to non-scientific communities. With the proposal of the powerpenia concept, dynapenia should be redefined to focus solely on skeletal muscle strength. Otherwise, the testing type and criteria to diagnose dynapenia in individuals would need to be revised to have coherence to its original definition. We assume that this is much more challenging, as it would be obligatory to create double assessment and double conjugated criteria for strength and power (which does not exist). As aforementioned, dynapenia's original concept presupposes that force and power are equivalent, and in turn regulated by the same factors. While some common physiological factors may underlie both muscular strength and power (e.g. skeletal muscle mass properties), it should be noted that the specific (and different) factors underpinning skeletal muscle power and strength production capacity have been widely reported in the scientific literature [2,12,21]. For instance, some factors can only be attributed to power tasks due to its supraspinal dependence [18]. By accepting both the introduction of the powerpenia and the revised dynapenia concepts, we contend that much more specific research and discussion will be obtained, as a given doctrine only develops in the presence of solid concepts. Also, more objective and effective intervention in clinical settings in diagnosing deficits in both skeletal strength and power as well as its specific training would be obtained. For instance, higher attention would be given to power training in aged individuals, as this mode of training appears to have greater influence on human physical function improvement and fall prevention [2,13]. Despite these arguments, we admit that some criticism may be raised against the introduction of the powerpenia concept. For instance, one may argue that powerpenia could cause some confusion to existing and accepted terminology of sarcopenia and dynapenia in research and clinical practice. However, nonacceptance of the term powerpenia would require a review of the sarcopenia (through the introduction of power testing and criteria) and dynapenia (through the differentiation between strength and power, and the introduction of double testing and criteria). We contend the latter option would be much more challenging. It could also be questioned whether a differentiation between dynapenia and powerpenia would lead to improved patient outcomes with treatment strategies or preventive approaches. As the factors between strength and power are not fully similar, we assume that much more specific intervention would be designed and thus better outcomes would be obtained.

The acceptance of the powerpenia concept would also raise awareness about the importance of skeletal muscle power in human health, as well as to promote powerpenia-modifying interventions. Skeletal muscle power has been considered a better predictor of functional performance in older adults than muscle strength [2,22], and it appears to be more important in preventing falls among older adults [23]. It is also associated with the health and function of several body structures, such as bone strength [24]. In addition, skeletal muscle power may indicate cognitive status [25], and serve as an indicator of the individual's motivation [18,26] and will to live [26]. Thus, specific intervention approaches would also

be designed to overcome skeletal muscle power deficits if the concept is introduced. In terms of exercise prescription, a higher emphasis would be given to the muscle contraction velocity during the resistance training exercises. Notably, this type of exercise modality known as power training has been shown to provide better improvements in skeletal muscle power outcomes than traditional (i.e. low-velocity) strength training [27–29] However, the effects of the power exercises appear to be task-dependent, with greater adaptations in power-based motor tasks (e.g., fast walking velocity and the five sit-to-stand test), rather than in functional tasks with endurance component (e.g., six-minute walking test) [29]. Finally, the promotion of the powerpenia concept could also help to reduce the reluctance that prevails in the scientific community regarding the safety and effectiveness of power training interventions in older adults. This is since convincing literature has pointed out that the skeletal muscle power capacity can be effectively improved with minimal risk among older adults, and this can also be associated with very relevant positive effects on human function and health among this population [13,29].

Existing evidence also suggests that skeletal muscle power reduces with a greater magnitude compared to strength in the presence of certain clinical conditions, but also with increased physical inactivity [30–33]. For instance, greater deficit of lower limbs power compared to strength has been found in patients with sarcopenia (i.e. -23% vs 11%, respectively) [30], Parkinson's disease (22% vs. 16%) [31], and type 2 diabetes (19% vs. 14%) [32]. The levels of physical (in)activity and sedentary behavior has also been associated with the lower limbs power in older adults, with stronger association than strength [33]. Together, this suggests that power deficit is a much more sensitive marker in the presence of disease and/or physical inactivity than strength (and also mass) to detect skeletal muscle impairment. This justifies why powerpenia should be considered as a biomarker within clinical and health settings.

The methodological approach to measure and classify individuals with powerpenia is complex, yet to be determined, and requires future investigation. There is a high diversity of power tests that mobilize different body regions (i.e. upper vs. lower limbs) and with different levels of motor demand and complexity (e.g. horizontal jump vs. sit-to-stand tests). We admit that the selection of power tests to assess the individual's powerpenia should depend on the individual's age group, functional status, and physical limitations. This fact is also justified by the ceiling effect that some tests may have on certain populations. For example, high performance may be obtained on the sit-to-stand test in the majority of the young adult population (or even physically active older adults), making the test irrelevant for this age group. In this case, another type of test may be more suitable as a health indicator (e.g. vertical jump). On the other hand, while young individuals may be able to perform a bilateral vertical jump without difficulty, older adults with an advanced age may be unable to do this task. In these situations where individuals are unable to perform the physical task, less demanding and complex tests should be selected to identify muscle power deficits [34], as the the five sit-to-stand test. Interestingly, the lower limb muscle power could be estimated through this test, and it has been shown to be a better predictor of mortality in older adults compared to walking test velocity [35]. Notably, with advancing age, humans first stop performing power-based tasks while maintaining considerable skeletal muscle strength and mass and continuing to perform maximal strength-based tasks [2]. This can be observed, for instance, when assessing the ability to perform a jumping task in older individuals where most with advanced age are not able to jump [36]. Thus, we contend that the type of tests capable of being performed by older adults should also be considered as a criterion for classifying the degree of powerpenia, in addition to the performance of the test itself, taking into consideration the individual's sex and ethnic background.

3. Future research prospects

For an effective introduction of the powerpenia concept and leverage for a new conceptual framework, we assert that widespread acceptance from researchers who investigate this topic is needed. We anticipate that some reluctance may come from some researchers. Thus, a group opinion by a panel of experts would be required in the near future, for instance by applying the Delphi method.

Another future prospect relates to the degree of relevance of skeletal muscle power, strength and mass as biomarkers of health. For instance, while several studies indicate that the rate of loss with age is higher for skeletal muscle power, followed by strength and then muscle mass [9,13,17], it is not clear whether the onset of decline has the same temporal order and which approach is the best to determine such onset. Considering the previous findings [9,12,17], we hypothesize that the onset and rate of decline of skeletal muscle with aging occurs in this order: first and higher in power, followed by maximal strength, and (ultimately) muscle mass (Fig. 1). However, as skeletal muscle atrophy with aging is muscle-specific [37], it is worth noting that differences between the onset of decline of these variables may be also muscle-dependent, meaning that there could be differences may exist between individuals of different sexes and ages [38,39].



Figure 1. Onset and rate of decline of skeletal muscle power, strength, and mass with advancing age: a hypothetical model. The dashed line means that all power or strength tasks are not able to be done by individuals.

A conceptual framework and operational algorithm would also need to be designed to assess and determine meaningful powerpenia. Besides identifying the power quantification approach and which power parameter would be most appropriate, as aforementioned, we contend that the conceptual framework should contemplate testing categories that are selected according to the individual's age, physical status, and physical and cognitive limitations. For instance, although lower limbs power is in general more relevant than that of the upper limbs, it is important to explore the importance of muscular power in the upper limbs in people who are unable to move their lower limbs, so powerpenia could be an inclusive concept.

The last general prospect we propose is to further explore the relevance of powerpenia in different clinical and health contexts. As modern humans in industrialized countries continue to adopt an increasingly inactive and sedentary lifestyle, and non-communicable diseases are increasing globally [40], the ability of current and future generations to generate musculoskeletal power may be adversely affected. As such, future research should investigate the impact of these conditions on powerpenia and other biomarkers through multicentric and multicultural study designs. For example, does the ability to perform powerbased tasks reflect the decline in muscle health and quality of life earlier than muscle strength or muscle mass in healthy and clinical individuals? Also, how is skeletal muscle power, strength and mass affected by different diseases compared to other biomarkers? Do powerpenia affect other populations than older

adults, such as children? By investigating these (and other) questions, the relevance of the powerpenia concept in different contexts could be determined.

4. Conclusion

In this current opinion manuscript, we propose the introduction of the powerpenia concept as a biomarker of healthy aging, to specifically address the skeletal muscle power loss due to aging, clinical conditions, and/or physical inactivity. This introduction is justified by the fact that skeletal muscle power and strength decline differently with aging and disease, are underlied by different factors, and have different influences on human physical function. Thus, we contend that the powerpenia concept should be distinguished from dynapenia (i.e., strength loss) and sarcopenia (i.e. muscle mass loss). Several research questions arise with this proposal to be addressed in the future, in particular the definition of the conceptual framework and operational algorithm to assess the individual's powerpenia. Together, but with different focus, sarcopenia, dynapenia, and powerpenia should be considered biomarkers of healthy aging.

Contributions

The *powerpenia* concept arose during the authors conversation on 21st of March 2023, during a lunch time at the Mauricio's restaurant in Porto Alegre, Brasil; during the Symposium on Neurophysiology and Neuromodulation in Sport, Exercise and Motor Rehabilitation, organized by the Universidade Federal do Rio Grande do Sul. SRF and CCM wrote the first draft of the manuscript. A roundtable was performed with all authors (SRF, CCM, SR, RP) on 8th of April 2023, where discussion was performed regarding the final version of the manuscript. Subsequently, all authors read and agreed to the manuscript's final version.

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Data and Supplementary Material Accessibility

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