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Review

Why Flexibility Deserves to Be Further Considered as a Standard Component of Physical Fitness: A Narrative Review of Existing Insights from Static Stretching Study Interventions

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Abstract: The utility of flexibility as a standard component of physical fitness has recently been questioned, sparking a heated debate among scientists. More specifically, it has recently been proposed to retire flexibility as a major component of physical fitness and as a result de-emphasis stretching from exercise prescriptions. The aim of this narrative review was to summarize and discuss the most recent evidence related to the chronic effects of static stretching (SS) on muscle strength, muscle power, muscle hypertrophy, and injury prevention in healthy individuals. A literature search was conducted using the electronic databases PubMed, SPORTDiscus, Web of Science, and Google Scholar up to November 2022. We only considered studies written in English that addressed the chronic effects of SS exercises on flexibility, muscle strength, muscle power, muscle hypertrophy, or injury prevention in healthy individuals. With reference to the existing knowledge, we concluded that flexibility deserves to be further considered as a standard component of physical fitness. This is based on the findings that in addition to flexibility, long-term SS training induces positive effects on muscle strength, muscle power, and muscle hypertrophy, irrespective of age and sex. There are also indications that long-term SS training could mitigate the risk of injury, although this remains a debatable topic. Furthermore, promising evidence shows that combining resistance training with SS exercises constitutes an effective approach benefiting muscle strength and hypertrophy more than resistance training alone. In conclusion, we would not support the recent suggestion that flexibility should be retired as a standard component of physical fitness and we would advocate for a continuous emphasis on the prescription of stretching exercises.

Keywords: range of motion; health; muscle strength; muscle power; muscle hypertrophy; functional performance; injury

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1. Introduction

Flexibility, which reflects the ability to move a joint through its complete range of motion, occupies an important role in sports, fitness, and clinical settings. More specifically, flexibility represents one of the main physical features of several sports (e.g., artistic gymnastics, ice skating, taekwondo, and karate) as it contributes to athletic performance [1–6]. Consequently, promoting flexibility due to the action of stretching (i.e., the physical act of elongating or lengthening the muscle—passively or actively) represents one of the prominent goals of training interventions in these sports. Additionally, previous studies indicate that improving flexibility through static stretching (SS) for instance, could contribute to mitigating the incidence of injury [7,8].

In this regard, flexibility has long been considered an important component of physical fitness, particularly a health-related fitness measure in addition to muscle strength, cardiorespiratory endurance, muscular endurance, and body composition [9]. However, the worthiness of flexibility as a major component of physical fitness has recently been questioned [10]. Particularly, Nuzzo [10] advocates the retirement of flexibility as a major component of physical fitness. While some of the arguments that Nuzzo [10] indicates are plausible, the main conclusion seems to be inappropriate. In addition, the effect of strength-versus-stretching exercises on flexibility has been the topic of a recent systematic review with a meta-analysis [11]. The authors conclude that strength training and stretching have similar effects on flexibility, supporting the claim by Nuzzo [10] that strength exercises across the full range of motion might suffice in improving flexibility. However, the same authors indicate that the studies included were highly heterogeneous with reference to the design, applied protocols, and recruited participants [11]. As such, the obtained outcomes must be considered with caution, and further research is warranted [11]. In line with Afonso, Ramirez-Campillo, Moscão, Rocha, Zacca, Martins, Milheiro, Ferreira, Sarmento and Clemente [11], a recent systematic review with a meta-analysis contrasting the effect of resistance training (RT) and stretch training on flexibility revealed similar improvements [12]. Specifically, the authors concluded that RT with an external load can enhance flexibility to a moderate magnitude, and that the flexibility gains between RT and stretching training are not significantly different [12].

However, it appears that the beneficial effects of stretching go beyond flexibility to cover other crucial components of physical fitness such as muscle strength and muscle power. Recently, Arntz, et al. [13] conducted a systematic review with a meta-analysis examining the chronic effects of SS exercises on muscle strength, muscle power, and flexibility in healthy individuals across the lifespan. The main results from 41 (randomized) controlled trials indicate that long-term SS exercises have the potential to improve muscle strength and power, albeit the improvement magnitude ranged from trivial to small. For flexibility, chronic SS exercises induced moderate to large enhancements. Another recent systematic review with a meta-analysis examined the effect of stretching on muscle strength in healthy individuals [14]. The main findings pointed toward a small positive effect of SS on muscle strength [14], supporting recent results [13]. In terms of muscle hypertrophy, there exist indications in the literature that stretching could benefit muscle volume. For instance, Panidi, et al. [15] revealed a positive effect of 12 weeks of SS training on the gastrocnemius cross-sectional area in adolescent female volleyball players. Moreover, in a recently published descriptive review of the literature, Nunes, et al. [16] conclude that passive low-intensity stretching does not seem to contribute to muscle hypertrophy and architecture. However, the same authors postulate that when stretching is carried out with a certain level of tensile strain, such as when loaded or added between strength sets, it may trigger muscle hypertrophy. In this same context, Van Every, et al. [17] studied the effects of RT alone versus RT combined with a loaded inter-set SS of calf muscles on muscle thickness and strength. The authors revealed that a combined loaded inter-set SS with RT improves muscle thickness of the soleus better than traditional RT alone. They further showed a modest advantage of a combined inter-set loaded SS with RT over RT alone on the isometric strength of the plantar flexors [17]. Similarly, Schoenfeld, et al. [18] postulated that integrating SS between the RT sets provides an additional muscle growth stimulus without increasing the duration of the training session and could, therefore, be considered a better option compared to RT alone [18].

Considering these studies, this narrative review aims to summarize and discuss the chronic effects of SS exercises on flexibility, muscle strength, muscle power, muscle hypertrophy, and injury prevention in healthy individuals. The goal of the present study is to advocate, based on the latest evidence, the worthiness of flexibility as an important component of physical fitness. As such, this study sought to answer the question of why flexibility should further be considered as a standard component of physical fitness.

2. Methods

In contrast to a systematic review where the question has to be well-defined and restricted, a narrative review allows one or more questions within a particular topic to be addressed [19]. In this sense, because the topic of this review is broad, we opted to summarize the literature in the form of a narrative review. As such, unlike systematic reviews, neither quantitative nor qualitative analyses of the literature is provided in this narrative review [19].

A literature search for the most recent evidence related to the topic was conducted using the electronic databases PubMed, SPORTDiscus, Web of Science, and Google Scholar up to November 2022. The following keywords were used either separately or in combination: static stretching, passive stretching, stretching exercises, range of motion, joint flexibility, muscle strength, muscle power, explosive strength, muscle hypertrophy, muscle volume, injury, and injury prevention. Only studies written in English and addessing the chronic effects of SS exercises on flexibility, muscle strength, muscle power, muscle hypertrophy, or injury prevention in healthy individuals were considered. Articles addressing the acute effects of SS on muscle strength and muscle power, or including individuals who were clinical patients, were not taken into account.

3. Chronic Effect of Static Stretching Exercises on Flexibility

There is strong evidence that chronic SS exercises improve flexibility [20–24]. For example, Nelson and Bandy [25] examined the effect of six weeks of SS training on hamstring flexibility in young healthy participants. They demonstrated significant hamstring flexibility gains as compared with the control group [25]. Medeiros and Martini [26] meta-analyzed the literature on the effect of different types of stretching exercises on ankle dorsiflexion flexibility in healthy individuals and revealed that SS and proprioceptive neuromuscular facilitation (PNF) induced flexibility gains, with larger effects of the former compared with the latter. Furthermore, the results indicate that ballistic stretching did not lead to any flexibility gains [26]. In another systematic review with meta-analysis, Borges, et al. [27] revealed that SS as well as PNF resulted in a similar hamstrings flexibility gain in sedentary and recreationally active young adults. Moreover, there is evidence from a systematic review with a meta-analysis that SS training leads to improved hamstring flexibility in healthy young adults [21]. Recently, Arntz, Markov, Behm, Behrens, Negra, Nakamura, Moran and Chaabene [13] reported the moderate to large effects of chronic SS exercises on flexibility in male and female participants, regardless of age. More specifically, the results indicate that passive SS exercises resulted in higher flexibility gains compared to active SS exercises [13]. Additionally, the results of the meta-regression analysis showed higher flexibility gains with an increase in repetitions per session, more time under SS per session, and with more total time under SS [13].

The mechanisms underpinning the chronic gains from SS exercise-related flexibility remain poorly defined. Two major mechanisms have been proposed in the literature. The first is related to sensory perception (i.e., sensory theory). Sensory theory indicates that chronic exposure to stretching results in an increased stretch tolerance [20,28,29], probably due to a modification of the subjective perception of discomfort [20,28,30], which seems to be caused by changes at the level of the nociceptive endings [22]. The second is called "mechanical theory", which suggests that stretching exercises change the muscle-tendon unit's (MTU) mechanical properties, namely through decreases in tissue stiffness or geometry (i.e., the addition of sarcomeres in series), or both [28,31]. In this sense, Blazevich, et al. [32] examined muscle-tendon lengthening and fascicle elongation and rotation during maximal plantar flexor stretches, in young healthy male participants aged 20 years. The stretching task consisted of ankle rotation from a 30° plantar flexion toward a dorsiflexion at 2°/s using an isokinetic dynamometer until the maximum tolerable stretch limit was achieved. The findings show that the maximal stretch was achieved through significant muscle (14.9%) and tendon (8.4%) lengthening. Furthermore, the findings indicate that participants with a greater range of motion displayed a lesser resistance to stretching and a greater passive joint moment (i.e., greater stretch tolerance) compared with those who were less flexible [32]. In addition, the same authors reveal that the more flexible participants displayed greater fascicle rotation during stretches than their less flexible counterparts [32]. Moreover, there is evidence that three weeks of twice daily SS exercises of the plantar flexors in young healthy males aged 18 years increased maximum tolerable passive joint moment (i.e., stretch tolerance) as well as muscle and fascicle lengthening [33].

It should be noted though that the two aforementioned mechanisms potentially underpinning chronic SS exercise-related flexibility adaptation are not conclusive. Freitas, Mendes, Le Sant, Andrade, Nordez and Milanovic [20] conducted a systematic review with a meta-analysis on the chronic effects of different types of stretching exercises (i.e., static, dynamic, and proprioceptive neuromuscular facilitation) on the MTU's structural properties. The aggregated data from the 26 studies indicate that three to eight weeks of stretching increases the stretch tolerance, but appears not to markedly affect the MTU's mechanical properties [20]. However, the same authors [20] failed to account for potential moderator variables, such as the type (e.g., static vs. dynamic) and the applied load of stretching (e.g., time under stretching), meaning that further studies are needed. Overall, if the goal is to improve flexibility, SS represents the most effective approach.

4. The Chronic Effects of Static Stretching Exercises on Muscle Strength and Power

The beneficial effects of muscle strengthening on health are consistent in the literature [34–36]. Muscle-strengthening activities are associated with a 10 to 17% decreased risk of all-cause mortality and major non-communicable diseases such as cardiovascular disease, cancer, and diabetes independent of aerobic activities in adults [37]. Therefore, developing muscle strength and power, regardless of age and sex, is crucial for promoting health and well-being.

The chronic effects of SS exercises on muscle strength and power were addressed in several original studies. For example, Hunter and Marshall [38] revealed increased jump height after chronic SS exercises (Δ1.3%, compared to a non-stretching control −0.3%) in physically active males aged 24 years. Additionally, 15 sessions with 20 min per session over three weeks of SS exercises showed an increase in eccentric peak torque at 60°/s and 120°/s (Δ8.5% and 13.5%, respectively), with an 11.2% increase in concentric peak torque at 120°/s of knee flexors in healthy active young adults [16]. Furthermore, Warneke, Konrad, Keiner, Zech, Nakamura, Hillebrecht and Behm [23] reveal significant improvement in maximal isometric strength of plantar flexors after six weeks of SS exercises performed on a daily basis in healthy young adults. Another recent study showed similar results reporting that long-lasting (one hour) SS daily for six weeks resulted in substantial muscle strength improvements of the stretched leg (Δ16.8%) with no significant changes in the non-stretched leg or in the control group [39]. Furthermore, the chronic effects of SS exercises on muscle strength and power have been the topic of a recent systematic review with a meta-analysis [13]. Data aggregated from 41 original studies indicate that, regardless of age and sex, chronic SS exercises benefit muscle strength and power, though trivial to small in magnitude (muscle power: standardised mean difference [SMD] = 0.18; 95% confidence interval [CI] = 0.12 to 0.25; muscle strength; SMD = 0.21; 95% CI = 0.10 to 0.33) [13]. Interestingly, in addition to the 95% CI, the authors report a commonly neglected, but informative, statistical variable, which is the 95% prediction interval (PI). In fact, the 95% PI accounts for the uncertainty of the effects expected in similar future studies [40–42]. The results show that most of the 95% PI for muscle strength was above zero indicating that chronic SS exercises may produce a positive effect in most of the upcoming studies. As to muscle power, both ends of the 95% PI are above zero implying that 95% of future investigations will show beneficial effects of chronic SS exercises [13]. These outcomes indicate that muscle strength and power will most likely benefit from chronic SS exercises. The outcome of the study from Arntz, Markov, Behm, Behrens, Negra, Nakamura, Moran and Chaabene [13], related to muscle strength, was supported by a recently published study [14]. More particularly, the authors meta-analyzed the literature on the chronic effect of stretching on muscle strength in healthy individuals; they reveal a small positive effect of long-term SS training on muscle strength [14].

The mechanisms under which chronic SS exercises improve muscle strength and power are still inconclusive. One speculation is that chronic SS exercises appear to stimulate muscle growth and, therefore, hypertrophy [43,44]. For instance, 12 weeks of SS exercises with five weekly sessions have been shown to induce larger enhancements in gastrocnemius cross-sectional area (CSA) and fascicle length of the stretched leg, as well as larger one-leg countermovement jump performance, compared to the control leg in adolescent female volleyball players [19]. In their narrative review, Nunes, Schoenfeld, Nakamura, Ribeiro, Cunha and Cyrino [16] suggest that low-intensity stretching appears not to trigger any change in muscle size and architecture, but high-intensity stretching does. However, this assumption is rather speculative and should therefore be investigated in future studies. Another potential theory discussed in the literature pertains to the mechanical properties of the MTU. Earlier studies report an increased MTU compliance following chronic SS exercises [45,46]. This could improve activities involving the stretch–shortening cycle (e.g., jumping, rebound bench press, and jogging) through better use of elastic energy [47–50]. However, it should also be noted that other studies did not report any change in the mechanical properties of the MTU after chronic SS exercises [20,30,51], leaving this research open for much debate in future studies.

To sum up, there is compelling evidence that chronic SS exercises generate positive effects on muscle strength and power, irrespective of age and sex (Figure 1). It is worth noting that SS exercises could particularly constitute a useful alternative for those who cannot afford a gym membership for RT and for injured individuals who cannot move their injured limb dynamically. In addition, the practice of RT is usually associated with a certain level of discomfort due to the stress and strain that the exercises induce. Consequently, SS could represent a more relaxing mode of training for those who cannot afford such discomfort. Therefore, flexibility should not be omitted as a standard component of physical fitness, as it contributes to muscle strength and power, both of which are crucial for maintaining/improving functional capacities and promoting health [34–36,52].

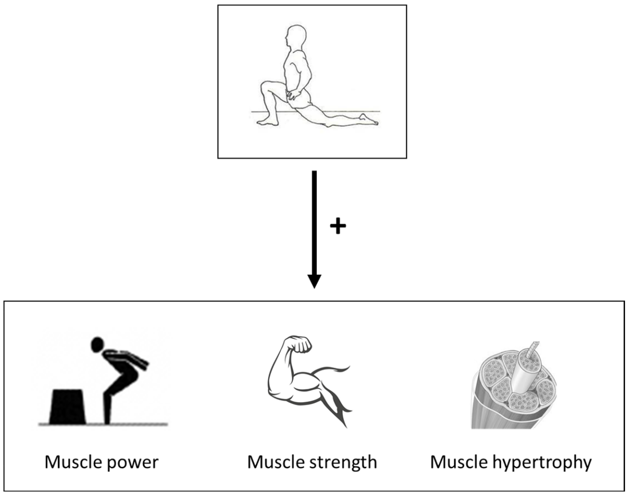

Figure 1. The chronic effects of single-mode static stretching training on muscle strength, muscle power, and muscle hypertrophy. The "+" stands for the positive effects of long-term static stretching training on the muscle strength and power [13,14,23,24,38,39,53] as well as muscle hypertrophy [15,24,39,44].

5. The Chronic Effect of Static Stretching Exercises on Muscle Hypertrophy

The chronic effect of SS exercises on muscle hypertrophy is an emerging topic. Promising evidence indicates that SS training exercises could favor muscle hypertrophy whether performed as a single mode [15,24,44] or combined with RT exercises [17,18,54]. More specifically, the results of the study of Panidi, Bogdanis, Terzis, Donti, Konrad, Gaspari and

Donti [15] show that 12 weeks of single-mode SS training induced significant improvements in the gastrocnemius cross-sectional area of the stretched leg with no observed changes in the contralateral control leg in adolescent female volleyball players. In the same context, Simpson, Kim, Bourcet, Jones and Jakobi [44] studied the effects of six weeks of single-mode SS training on the muscle architecture of the gastrocnemius in male healthy young adults. The results indicate that there is an improved gastrocnemius muscle thickness and a greater fascicle length increase in the lateral compared to the medial gastrocnemius after training [44]. More recently, Warneke, Zech, Wagner, Konrad, Nakamura, Keiner, Schoenfeld and Behm [24] examined the effect of six weeks of daily SS training of plantar flexors on muscle thickness of the medial and lateral gastrocnemius in healthy physically active male and female participants. The same authors report a 4% to 14% increase in muscle thickness following training, regardless of sex [24].

On the other hand, performing SS exercises between the RT sets appears to be a promising training approach leading to a greater muscle hypertrophy than the RT alone. This is what a recent study by Van Every, Coleman, Rosa, Zambrano, Plotkin, Torres, Mercado, De Souza, Alto and Oberlin [17] demonstrates. In fact, the authors revealed that a combined loaded inter-set SS with RT improves muscle thickness of the soleus better than the traditional RT alone. The same authors further revealed a modest advantage of a combined inter-set loaded SS with an RT over an RT alone on the isometric strength of the plantar flexors [17]. Evangelista, De Souza, Moreira, Alonso, Teixeira, Wadhi, Rauch, Bocalini, Pereira and Greve [54] investigated the effect of eight weeks of single-mode RT versus RT with integrated SS exercises between the sets on biceps brachii, triceps brachii, rectus femoris, and vastus lateralis hypertrophy in sedentary healthy adults. The results indicate similar muscle thickness gains of biceps brachii, triceps brachii, and rectus femoris with greater gains in vastus lateralis muscle thickness following the combined RT and SS exercises compared to the RT alone [54]. The authors conclude that integrating the SS exercises with RT seems to have a greater benefit on muscle hypertrophy compared with the RT alone. Furthermore, Schoenfeld, Wackerhage and De Souza [18] postulate that integrating SS between the RT sets provides an additional muscle growth stimulus without increasing the duration of the training session and could, therefore, be considered a better option compared to the RT alone [18].

Overall, there is emerging evidence that single-mode SS training contributes to muscle hypertrophy (Figure 1). Additionally, recent studies indicate an advantage of combining the RT with the SS exercises integrated between the sets compared to the RT alone (Figure 2). However, more research is warranted to substantiate the existing outcomes.

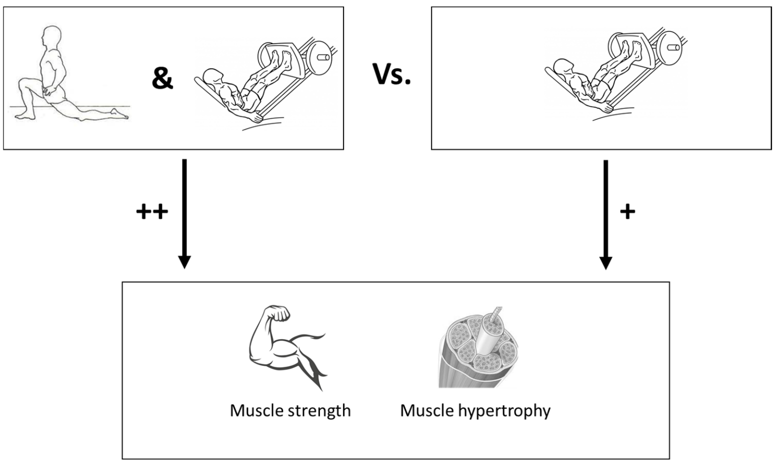

Figure 2. The e ffects of combined resistance training and static stretching versus resistance training only on muscle strength and hypertrophy. Recent evidence indicates an advantage (++) of combining RT with static stretching exercises integrated between the sets compared to resistance training alone (+) [17,18,54].

6. Chronic Effect of Static Stretching Exercises on Injury Prevention

There are indications in the literature that increasing flexibility could mitigate the incidence and risk of injury [7,55–57]. For instance, Cross and Worrell [58] studied the effects of SS training on the incidence of lower extremity musculotendinous strains in young football players. The same authors report that the incorporation of SS exercises could lead to the decreased incidence of musculotendinous strains. Findings from a meta-analysis of the literature [59] indicate that poor flexibility in the lateral flexion and a restricted range of motion in the hamstrings can contribute to the development of low back pain, regardless of age and sex. Additionally, there is an indication that reduced trunk flexibility in children is associated with lumbar stress fracture [60]. Moreover, it is well-known that SS exercises decrease MTU stiffness [45,46]. This increase in the muscle–tendon compliance, according to Witvrouw, et al. [61], is needed for activities conducted in the stretch–shortening cycle to effectively store and release a high amount of elastic energy. The same authors suggest that when the level of MTU compliance is insufficient, there is a risk that the demands in energy absorption and liberation rapidly surpass the capacity of the MTU, which once it has initially occurred, could lead to a higher risk of injury [61]. Other studies support the fact that increasing MTU compliance might allow for more efficient use of elastic energy during activities involving the stretch–shortening cycle (e.g., jumping, rebound bench press, jogging) [47–50]. Woods, Bishop and Jones [7] introduced the "non-injury zone" (NIZ) theory. The NIZ stands for the range of motion through which a given muscle can freely move without any risk of injury. Any movement beyond the NIZ would lead to an injury of the respective muscle. In this sense, if the length of the muscle increases due to stretching, this would widen the NIZ. This expansion in the NIZ would allow a greater range of motion through which the muscle can freely move without exposing it to a greater risk of injury [7]. However, this is hypothetical and yet to be empirically proven. Recently, Behm, Kay, Trajano, Alizadeh and Blazevich [57] synthesized the available literature related to the effects of stretching on injury prevention and concluded that chronic stretching, particularly SS, has the potential to mitigate the incidence of musculotendinous injury. This particularly refers to running-based sports [57]. According to the same authors, the beneficial effects of SS exercises on the reduction in the incidence of injury seem to be due to the reduced MTU stiffness (i.e., an increased MTU compliance) or longer muscle lengths (an altered force–length relationship), among other factors [57].

We acknowledge that other studies did not report any benefits of SS on injury prevention [62–64]. This means that the effect of SS on injury prevention still constitutes a debatable topic in the scientific literature. However, we suggest that in addition to the potential direct effects of SS training on reducing the risk of injury [57], there may also be indirect effects due to the positive effect on muscle strength, which is proven to be associated with the reduced risk of injury [65–67]. Nevertheless, future high-quality studies exploring the potential cause and effect of SS training on injury prevention are urgently needed.

7. Preliminary Static Stretching Training-Related Recommendations

The recent systematic review with a meta-analysis from Arntz, Markov, Behm, Behrens, Negra, Nakamura, Moran and Chaabene [13] reports relevant practical recommendations, which included the preliminary dose–response recommendations related to the chronic effects of SS exercises on muscle strength. More specifically, the outcomes of the meta-regression indicate that there are greater effects on muscle strength with a higher number of repetitions per stretching exercise and session (i.e., more repetitions were associated with larger muscle strength improvements). Flexibility gains, on the other hand, are associated with more repetitions per session, more time under stretching per session, and more total time under stretching [13]. Nevertheless, these recommendations are preliminary and need to be confirmed/broadened by future studies.

8. Why Flexibility Should Further Be Considered as a Standard Component of Physical Fitness

There is clear evidence that the beneficial effects of long-term SS training alone go beyond flexibility to also cover muscle strength [13,14,24], muscle power [13], and even muscle hypertrophy [24,44]. There are also indications that SS training decreases the risk of injury [7,55,56,59,60]. Therefore, we would not support the suggestion that flexibility should be retired as a major component of physical fitness [10] and we would advocate for a continuous emphasis on the prescription of stretching exercises. While we admit that the effects of SS training on muscle strength and power are rather trivial to small [13] and that RT can provide a relatively greater magnitude of gain, promising evidence indicates that combining RT with SS exercises constitutes an effective approach benefiting muscle strength and hypertrophy more than RT alone [17,18,54].

It is worth noting that stretching alone might seem to be appropriate for youth and older adults, especially for those who cannot afford to perform RT exercises and in the context of rehabilitation. In fact, stretching training can be considered a sort of low-intensity RT that would be safe and effective for children who lack the technical competencies to perform more complex strength exercises, and for untrained and older individuals as well as individuals at the beginning of the rehabilitation phase.

9. Future Research Perspectives

The underpinning mechanisms of the concomitant increase in flexibility, muscle strength, muscle power, and muscle hypertrophy after chronic SS exercises are yet not fully elucidated. Therefore, further studies are needed. Additionally, whether the findings presented above apply to dynamic stretching remains unclear. However, existing evidence indicates that dynamic stretching benefits flexibility [68,69] although not in the same way as SS does [69]. Furthermore, unlike long-term SS, dynamic stretching does not seem to promote any muscle strength [14] or hypertrophy gain [68]. Nevertheless, compared with SS, the body of literature about dynamic stretching is limited, thus future research is warranted. Moreover, while there is extensive evidence relating to the effects of SS training on injury prevention, there is little available information on dynamic stretching, representing another research gap and hence an area for future investigations.

10. Conclusions

Flexibility has long been considered a standard component of physical fitness and should further be considered as such. There is compelling evidence indicating the positive effects of chronic SS exercises on muscle strength, muscle power, and muscle hypertrophy, all of which are well-established fitness parameters for better functional performance and the promotion of health and well-being, regardless of age and sex. In summary, based on the existing knowledge, we would advocate for the further consideration of flexibility as a standard component of physical fitness.

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