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A review of the effects of static stretching in human mobility and strength training as a more powerful alternative: Towards a different paradigm

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RESEARCH NOTE

ABSTRACT

Flexibility is a measurable physical capacity considered as a key component of physical fitness. Poor flexibility is usually attributed to excessive tension exerted by the antagonist muscles of the movement and, supported by weak scientific evidence, passive stretching is considered as the most effective intervention in the promotion of the muscle extensibility, in attempting to improve mobility. The proposal of this paper is a review of the effects of static stretching in human movement and a presentation of strength training as a more robust alternative based on scientific evidence. First, we try to define which factors influence the ability of the human body to move into their functional safety range of motion. Second, we present a critical scientific literature review of the effects of static stretching in the promotion of range of motion, injury prevention, and sports performance. Third, we propose alternatives to static stretching such as proprioceptive neuromuscular facilitation, dynamic stretching, and especially strength/resistance training, in the promotion of a better range of motion. Finally, we conclude that perhaps problems of flexibility/mobility should not be addressed with static processes, but with movement.

Keywords: flexibility, mobility, range of motion, stretching, strength training, review

INTRODUCTION

Flexibility is a measurable physical capacity considered as a key component of physical fitness (Heyward, 2006; Knudson, 2007; Pescatello, 2014), thereby contributing to the health and performance of joints and the musculoskeletal system. Sports sciences commonly apply the term "flexibility" to denote the ability to move a joint through its maximum range of motion or ROM (Heyward, 2006; Pescatello, 2014; Zatsiorsky & Prilutsky, 2012). Notwithstanding, the human body moves through rotations around joint axes, meaning that "mobility" is probably a more accurate term to describe this ability (Harvey et al., 2017; Medeiros & Martini, 2018), even because it is the word that, in most English-language dictionaries, denotes the ability to move.

In practical terms, the focus is usually on muscle extensibility (Levangie & Norkin, 2011; Lippert, 2011), and therefore flexibility — or mobility — problems are often attributed to excessive tension exerted by the antagonist's muscles (Nordez et al., 2017), which may be producing such tension to protect the joint. However, in recent years there has been increasing evidence that muscle weakness (Hurley, 1999; Roos, Herzog, Block, & Bennell, 2010; Waryasz & McDermott, 2008) is a major factor behind reduced mobility (Zatsiorsky & Prilutsky, 2012). Consequently, training muscle contractility is likely to improve mobility.

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Furthermore, the role of bone and joint structure, fascia, ligaments and nerves (both signal regulation and actual physical deformation, as shortening and elongation or stretching) have been recognized as important limiters of ROM (Junior, 2004; Kapandji, 2006; Levangie & Norkin, 2011; Weppler & Magnusson, 2010; Zatsiorsky & Prilutsky, 2012), and their extensibility is much less modifiable than muscle extensibility or strength. Additionally, ROM can be passive (i.e., provoked by an external agent, such as gravity, another person of the same person in another body part) or active (i.e., provoked by an internal agent — internal forces, intrinsic to the involved regions) (Heyward, 2006; Zatsiorsky & Prilutsky, 2012).

Regardless of terminology and of the quality of supporting evidence, stretching emerges as an intervention that elongates the tissues in attempting to improve mobility (Knudson, 2007; Lippert, 2011; Nordez et al., 2017). However, we should point out that movement and, naturally, contraction, is three-dimensional. Considering the three geometric axes that configure the muscle's structure, it should be noted that while stretching elongates the tissue along its longest axis, it diminishes the physiological cross-sectional area (PCA) on the other two – i.e., it promotes muscle transverse shortening. On the contrary, it is muscular shortening along the long axis that promotes an increase in the tissue's PCA, thus lengthening the other two axes.

So, paradoxically, shortening lengthens the tissue on two out of three axes, while stretching only lengthens the tissue on one axis out of three. Still, world-acclaimed guidelines such as those of the National Strength and Conditioning Association and the American College of Sports Medicine recommend the utilization of stretching in all exercise programs, as a means of promoting muscular elongation and flexibility (Clark, Luccet, & Sutton, 2011; Pescatello, 2014). Notwithstanding, the three-dimensional analysis of movement axes reveals that it is impossible to move without elongating along at least one of the involved axes.

Therefore, all training, including movement, is, by definition, training of shortening and stretching cycles (SSCs) (Kenney, Wilmore, & Costill, 2012). Ergo, resistance training is also, inherently, one way to elongate. Moreover, we should take into consideration that in the active modality of stretching, the internal forces that stretch the targeted tissue area in fact forces produced by muscles that are shortening, with contraction of certain muscles being the key for the stretching of others.

Of note, there seems to persist a misconception in the sports communities, stating that stretching would be a protocol of mild intensity, while flexibility would be a protocol of high intensity. First and foremost, flexibility is a physical capacity, while stretching is a means of developing said capacity. Secondly, stretching can vary in intensity, from light to heavy (Apostolopoulos, Metsios, Flouris, Koutedakis, & Wyon, 2015), like any other training parameter. Thirdly, this is also inconsistent with our terminology concerning other training factors. For example, resistance training using 1RM, 10RM, or even non-maximal repetitions is always considered as a form of strength training. However, if we applied the previous logic, only 1RM would be considered strength training. Therefore, stretching does not imply an intensity; instead, it can present a range of intensities.

It has been further suggested that the inclusion of stretching protocols in training programs is based more strongly on tradition than on science (Baxter, Naughton, Sparks, Norton, & Bentley, 2017). Our goal is, therefore, to review the known acute and chronic effects of passive and active static stretching protocols in multiple dimensions (e.g., warm-up, performance, injury prevention). Building upon the limitations of those protocols, we will review three alternative methods for developing a range of motion: (i) proprioceptive neuromuscular facilitation; (ii) dynamic stretching; and (iii) resistance or strength training.

Static stretching: From promises to actual effects

Static stretching is, perhaps, the most commonly applied stretching method across general, athletic, and clinical populations (Kay & Blazevich, 2012), and it seems consensual that it promotes increases in passive ROM (Medeiros & Martini, 2018; Thomas, Bianco, Paoli, & Palma, 2018), whether through an increase in muscle extensibility or growth intolerance to stretching (Blazevich et al., 2014; Freitas et al., 2017; Konrad & Tilp, 2014; Lima, Carneiro, Alves, Peixinho, & Oliveira, 2015), namely through changing of the perceived discomfort associated with stretching (Medeiros & Martini, 2018). One of the main arguments in support of static stretching is its alleged role in injury prevention. However, chronic applications of stretching to reduce the incidence and/or graveness of muscle contractures are ineffective and may even increase pain perception, as well as provoke numerous deleterious secondary effects, such as numbness, swelling, and cutaneous lesions (Harvey et al., 2017).

It has also been suggested that most musculoskeletal injuries occur far from the ROM limits (Thacker, Gilchrist, Stroup, & Kimsey, 2004), raising doubts concerning the relevance of increasing ROM. Indeed, we have to consider that more ROM may allow the joint to move into perilous situations while demanding the nervous system to control a higher number of degrees of freedom, paradoxically increasing the risk of injury (Magnusson, 1998). Moreover, it is common for guidelines to propose that stretching is performed until slight discomfort is achieved (ACSM, 2018). However, this implies that the joint is already being confronted with its limits, and it might be speculated that this closeness to the limits is potentially dangerous since we are dealing closely with joint limits. Special care should be taken when passive stretching is being conducted since the healthy limits of ROM may easily be surpassed by the application of external forces (Levangie & Norkin, 2011).

A review conducted by Herbert and Gabriel (2002), concluded that stretching is a highly ineffective intervention, requiring approximately 23 years to prevent one injury. Furthermore, there have been reports of stretching-induced injuries (Bracko, 2002). In addition, when static stretching is associated with a slight reduction in injury risk, other warm-up activities are also present, and it is therefore impossible to state that such risk reduction is due to stretching or to the other protocols (McHugh & Cosgrave, 2010). More recently, Behm, Blazevich, Kay, and McHugh (2016) performed a systematic review showing that stretching does not reduce injury risk. As a result, even the ACSM has stated that there is no consistent link between stretching and reduction of injury risk (ACSM, 2018).

An extensive systematic review by Lauersen, Bertelsen, and Andersen (2013) verified that both resistance and "proprioceptive" training protocols (under quotation marks because all exercise promotes proprioceptive adaptations, and because the so-called proprioceptive protocols are protocols under unstable surfaces and request too much more than merely proprioception) were effective in reducing injury risk while stretching protocols were not.

Passive static stretching is considered a useful tool for improving ROM and is routinely used in training protocols (Behm et al., 2016). However, the ability to voluntarily regulate ROM, actively controlling movement, is decisive for joint health, and therefore active ROM may be considered functional (McHugh & Cosgrave, 2010; Sharman, Cresswell, & Riek, 2006), while passive ROM may not. A systematic review has shown that improvements in classical measures of ROM do not necessarily translate to increments in functional mobility tests (Stathokostas, Little, Vandervoort, & Paterson, 2012). The study of Moreside and McGill (2013) has shown that an increase in passive ROM may even negatively transfer to active ROM. Moreover, passive stretching may increase the delay in the neuromuscular response, increasing the risk of injury (Minshull, Eston, Bailey, Rees, & Gleeson, 2013). Importantly, many purportedly active stretching protocols are actually pseudo-active, since – as we have already stated – one body part is being used to impose external forces on another part. For example, in the frog position, the arms are actively pushing the knees down, thereby passively stretching the adductor region.

Similar to active static stretching, passive static stretching induces a slight acute impairment of performance in respect to strength, speed, and agility; however, the chronic effects on strength might be positive (Shrier, 2004). This concurs with our argument that static stretching is but a form of isometric strength training: one where a specific group of muscles works isometrically in a shortened position, while their antagonists work isometrically in a lengthened position. Notwithstanding, these chronic effects of stretching on strength are derived from studies with questionable methodologic protocols, usually with a high risk of bias (Medeiros & Martini, 2018). Therefore, it might not be surprising that some studies report that chronic stretching is no better than a control group for improving strength (LaRoche, Lussier, & Roy, 2008), while others report that adding stretching to a resistance training protocol may enhance strength gains (Kakkonen, Nelson, Tarawhiti, Buckingham, & Winchester, 2010), and still, others describe how adding stretching to a resistance training protocol actually impaired strength gains (Bastos et al., 2013).

Conversely, the acute effects depressing performance seem to be well established in the literature (Avela, Kyrolainen, & Komi, 1999; Haddad et al., 2013; McHugh & Cosgrave, 2010; Nelson, Driscoll, Landin, Young, & Schexnayder, 2005; Rubini, Costa, & Gomes, 2007; Sayers, Farley, Fuller, Jubenville, & Caputo, 2008; Simic, Sarabon, & Markovic, 2012). Likely, such effects are neurally mediated, as they may affect both the stretched and the non-stretch muscles (Masugi, Obata, Inoue, Kawashima, & Nakazawa, 2017). A more controversial topic pertains the duration of each stretching, with (Matsuo et al., 2013) denoting that protocols lasting from 20 seconds to 300 seconds similarly impaired strength, while (Behm et al., 2016) showed that such impairments were exponentiated by stretches lasting for 60 seconds or more.

Alternatives to static stretching

A review of chronic effects of stretching protocols on the ROM of the lower limbs (Thomas et al., 2018) concluded that active static, passive static, ballistic, and proprioceptive neuromuscular facilitation (PNF) were all equally effective in increasing passive ROM.

Proprioceptive neuromuscular facilitation

PNF is a group of stretching techniques that combine passive static stretching with muscle contractions (more usually isometric, but also concentric, depending on the specific technique applied), and is considered a powerful tool for improving mobility (ACSM, 2018; Thomas et al., 2018), with gains in passive ROM superior to those obtained with static stretching (Behm et al., 2016). Despite its popularity, we still do not have a solid understanding of the mechanisms underlying its effects (Hindle, Whitcomb, Briggs, & Hong, 2012). There are several techniques within PNF, but perhaps the two most widely studied are contract-relax (CR) and contract-relax-contract antagonists (CRCA). Since these PNF techniques are usually performed with high intensity, the subjects are exposed to potentially increased injury risk (Hindle et al., 2012; Kay, Dods, & Blazevich, 2016). A modified CR method allows the joint to return to a previous position, and contractions are performed further away from the joint ROM limits. This latter method is as effective as more mainstream approaches while reducing the risk of injury (Kay et al., 2016).

Interestingly, the gains obtained in both passive and active ROM testing seem to increase in par with the increase in the duration of the isometric contractions (Cayco, Labro, & Gordon, 2019; Hindle et al., 2012; Rowlands, Marginson, & Lee, 2003), strongly suggesting that the component of voluntary contraction is determinant in the effectiveness of PNF methods, as is what distinguishes them from traditional static stretching. However, the acute effects of PNF also impair strength levels, although less than static stretching, and there is no established association between the application of these methods and injury risk (Behm et al., 2016).

Dynamic stretching

In a very real, non-allegorical sense, dynamic stretching is but a form of strength training where body weight and gravity are the only variables involved, i.e., there is no additional external load (Opplert & Babault, 2017). If a person performs an overhead squat, we call it "mobility training". If the same person performs the same overhead squat, but with a superimposed barbell, we suddenly call it "resistance training". They are pretty much the same protocol; the main difference is the magnitude of the external load – and on both examples, there is a confront between body and resistance. Dynamic stretching increases active and passive ROM (Opplert & Babault, 2017), and since the subject only moves through the active ROM, dynamic stretching usually does not relate so closely with the maximum ROM (Behm et al., 2016). In our view, this constitutes a more secure type of exercise than the more commonly used static stretching.

Acutely, dynamic stretching could be hypothesized to improve performance. However, studies have revealed that it is, at best, slightly beneficial (Behm et al., 2016; Opplert & Babault, 2017; Peck, Chomko, Gaz, & Farrel, 2014). This fact might imply some redundancy: exercises specifically designed to promote dynamic stretching will probably add little to regular warm-up exercises, which also require movement and, therefore, imply dynamic stretching. Overall, the small improvements in performance after performing dynamic stretching may be attributable to the voluntary muscle contractions that are applied, possibly through the post-activation potentiation phenomenon (Opplert & Babault, 2017).

Strength/resistance training

Since all movement occurs in the form of stretch and shortening cycles or SSCs (Kenney et al., 2012), it is no surprise to claim that resistance training is a form of stretching and may, therefore, improve mobility (Haff, 2006). But strength training is an active, voluntary, dynamic form of stretching. Indeed, strength training is dynamic stretching. Often, strength training is performed against external resistances, but this is not mandatory. Moreover, strength training has been shown to improve mobility in sedentary adults (Leite et al., 2017; Monteiro et al., 2008; Santos et al., 2010) and elders (Carneiro et al., 2015), as well in trained adults (Júnior, Leite, & Reis, 2011; Souza et al., 2013) and in elite athletes (Saraiva et al., 2014). Furthermore, resistance training has been shown to be the most effective method for injury prevention (Attar, Soomro, Sinclair, Pappas, & Sanders, 2016; Lauersen et al., 2013; Suchomel, Nimphius, & Stone, 2016; Thacker et al., 2004).

In a comparative study, Morton, Whitehead, Brinkert, and Caine (2011) showed that resistance training produced greater mobility gains than passive static stretching. A 16-week study in sedentary women compared resistance training only, passive static stretching only, and resistance training plus passive static stretching, and found that all protocols produced similar improvements in mobility (Simão et al., 2011). In a study with ballerinas (Wyon, Smith, & Koutedakis, 2013), resistance training (named dynamic stretching by the authors), low-intensity passive static stretching and high-intensity passive static stretching were compared (although it is not very clear how intensity level was determined). The three groups exhibited similar improvements in passive ROM, but for active ROM the resistance training group showed superior increments. In trained men, resistance training only was as effective in improving mobility as resistance training plus passive static stretching (Bastos et al., 2013).

Overall, these studies concur to underline the positive role of strength training on mobility. The first possible mechanism is obvious: strength exercises imply alternated cycles of shortening and lengthening, and so they constitute a dynamic form of elongating the muscle tissue. The second mechanism likely relies on a more precisely regulated coactivation of the agonistic and antagonistic muscle pairs (Dal Maso, Longcamp, & Amarantini, 2012; Duchateau & S., 2014; Kandel, Schwartz, Jessel, Siegelbaum, & Hudspeth, 2013; Remaud, Guével, & Cornu, 2007). Regarding this very regulation, and in light of the evidence mentioned above on the coactivation phenomenon, in the absence of joint or bone impediments, poor mobility may result from an exaggerated co-activation of the antagonistic muscles and/or muscle weakness of the agonistic muscles. In both cases, the voluntary movement fails to produce an adequate balance of forces and its mobility becomes reduced. In this vein, big differences between active and passive ROM may reflect a weakness of the agonistic muscles, in which case strength training will be more effective than passive stretching of the antagonists (Zatsiorsky & Prilutsky, 2012).

It should be underlined that the muscle does not stretch by itself, but only when faced with a winning external force (Hamill & Knutzen, 2003). In the absence of such external forces, the muscle always shortens, as the intrinsic mechanics of muscle contraction always attempt to promote concentric actions (Widmaier, Raff, & Strang, 2006). Moreover, the nervous system can regulate the frequency and intensity of the signals to both alpha and gamma motoneurons, both those signals always promote shortening and never muscle stretching (Kenney et al., 2012; Widmaier et al., 2006). Therefore, stretching is not an active property of the muscles; instead, for muscles to stretch, different muscles have to shorten and force the others to stretch (Latash, 2008). The muscle always produces forces, and mobility derives from the equilibrium of those forces (Levangie & Norkin, 2011) – i.e., mobility (as its synonymous "flexibility") is a product of muscle contraction.

In this respect, even isometric training may prove useful since the muscle performs short-scale stretching and shortening cycles (Kay & Blazevich, 2012; Latash, 2008). Isometric strength training has been shown to minimize antagonistic co-activation, therefore improving agonistic contractility (Dal Maso et al., 2012; Lee, Kang, & Shin, 2015). The same was verified by (Kofotolis & Kellis, 2006), who applied PNF-like protocols but having removed the passive stretching component, meaning they applied isometric strength training. Of interest, the improvements in strength were not limited to isometric evaluations but extended to dynamic evaluations. Moreover, the authors showed improvements in active ROM, even though the isometric training was conducted far from the ROM limits. Similar results have been reported by (Ferber, Osterning, & Gravelle, 2002) and (Kofotolis, Vlachopoulos, & Kellis, 2008). In conclusion, unlike what is mentioned in several guidelines, mobility can improve even when working far from the existing ROM limits, which constitutes a very relevant security factor. In addition, another major advantage of isometric training is the possibility to adjust the load to every intended angle properly.

FINAL REMARKS: TOWARDS A NEW PARADIGM FOR DEVELOPING A RANGE OF MOTION

All movement presupposes SSCs, i.e., all movement requires both shortening and lengthening of the musculoskeletal system (Kenney et al., 2012). Even isometric training requires micro-movements (since the muscle has to generate force), and therefore requires micro-scale SSCs. As we have previously seen, static stretching can be considered an isometric stimulus where the agonist's muscles are in a shortened position, while the antagonist's muscles are in a lengthened position. On the other end of the spectrum, all dynamic strength training implies both shortening and lengthening. This presents four major implications: (i) strength training represents a great method for improving mobility; (ii) shortening training lengthens two of the three axes of movement; (iii) since we do not apply passive techniques in strength training, we should rethink the application of passive techniques such as passive static stretching; (iv) and even isometric exercise far from the ROM limits can be effective in improving mobility.

Perhaps problems of flexibility/mobility should not be addressed with static processes, but with movement.

PRACTICAL RECOMMENDATIONS

We suggest that the commonly applied term "flexibility" is replaced by "mobility", recognizing the multi-factorial aspects that condition this quality (e.g., bone and joint structure, the interplay between agonistic and antagonistic muscle groups). We also suggest that the commonly applied expression "dynamic stretching" is replaced by "strength exercise", recognizing the enormous similarity between definitions and the physical relationship between body and resistance. Furthermore, there are several methods for improving mobility, and the promises of static stretching (both active and passive) have met with disappointing results. At the same time, strength training has emerged as a powerful method for generating improvements in several aspects of health and performance, one of them being mobility.

Therefore, we recommend that practitioners apply strength training methods for improving the mobility of their athletes or clients. We further invite practitioners to prefer active over passive methods, promoting the ability to produce movement voluntarily and avoiding damaging the invisible, complex, under the skin structure that is the human body. Finally, we should rethink the concept that more ROM is always better because this is false and may peril the integrity of the joint structure and therefore expose the athlete to an increased risk of injury.

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