Effects of Lower Limbs Stretching on the Neck Range of Motion: Preliminary Evidence for Myofascial Sequence?

Jenny Calgaro[1], Lorenza Bonaldi[2], Simona Mrakic Sposta[3,4], Caterina Fede[1], Antonio Stecco[5], Carmelo Pirri[1,*] and Carla Stecco[1]

[1]*Department of Neurosciences, Institute of Human Anatomy, University of Padova, 35121 Padova, Italy*

[2]*Engineering Department, University of Padova, 35131 Padova, Italy*

[3]*Department of Human Sciences and Promotion of the Quality of Life, San Raffaele Roma Open University*

[4]*Institute of Clinical Physiology-Milan, National Research Council (IFC-CNR), Italy*

[5]*Rusk Rehabilitation, New York University School of Medicine, New York, NY 10016, USA*

Abstract: In recent years, various studies have demonstrated that the fascia can transmit the mechanical tensions generated by muscle activity over a distance. However, it is not yet clear whether this transmission follows precise anatomical lines. The present study aims to understand if the exercises at a distance can influence the range of motion of the neck, and if the effects are different by performing the exercises in various directions. The study was attended by 30 healthy volunteers aged between 19 and 32 years. Anterior flexion of the neck was checked before the protocols and retested to compare the difference after stretching the hamstrings and adductors. All evaluations were performed by the same operator using an electronic goniometer. Cervical ROM increased during both procedures, but after the hamstrings stretch it increased significantly more than after the adductors stretch (6.22° versus 1.44°). This study highlighted how fascia can transmit forces at a distance, but only according to precise myofascial sequences. Consequently, it is important to know the fascial organization in order to properly train the fascial system.

Keywords: Fascia, Myofascial chain, Posterior line, Stretching, Range of motion.

1. INTRODUCTION

In recent years many works [1-5] have shown that a substantial percentage of the force exerted by a muscle is not transmitted from the tendon to the bones, but to the fascia thanks to a series of myofascial connections. The fascia has sufficient stiffness to transmit 15% [6] to 37% of muscle force to adjacent structures rather than reaching the muscle tendon insertion, and the extent of this force transmission depends on the length and relative location of these structures [7]. Furthermore, these forces in the fascia could be distributed over a distance, affecting the range of motion of segments far from the initial muscle contraction [8]. In a systematic review, Wilke *et al*. [9] demonstrated that there is good evidence for the existence of at least three myofascial chains based on anatomical dissection studies: the Superficial Back Line, the Back Functional Line and the Front Functional Line. However, the functional relevance of this fascial continuity has been a matter of debate. Wilke *et al* (2016) demonstrated how the transmission along the myofascial chains can contribute to the correct functioning of the movement system [10]. As demonstrated by Hyong *et al*. (2013) e Wilke *et al*. (2016), passive stretching exercises of the hamstrings can improve the range of motion of the cervical spine [11, 10]. Similarly, Aparicio *et al*. (2009) demonstrated that neck muscle release corresponds to an increase in hamstrings flexibility [12]. With ultrasound it was possible to note a movement of the gastrocnemius fascia during anteversion of the pelvis [13] and also during the flexion of the cervical spine [14] suggesting a myofascial continuity between the cervical spine and the lower limbs. In agreement with the above, another study by Wilke *et al*. (2020) [15] shows through a high-resolution ultrasound device that maximum dorsal extension of the ankle is associated with significant caudal displacements of the semimembranosus muscle and its encapsulating fascia. Interestingly, the ankle was moved passively between plantar flexion and maximal dorsiflexion using a dynamometer without muscle activation. This long-distance effect is called with a term that was coined by Wilke *et al*. (2016) [10] as "*remote effect",* to indicate the effects found in a part of the body other than the one in which the stretching was administered. Thus, a related hypothesis is that myofascial connectivity contributes to the effects of "remote stretching", thanks to forces transmission through myofascial chains. Thus, the myofascial release of one point in the chain

*Address correspondence to this author at the Department of Neurosciences, Institute of Human Anatomy, University of Padova, 35121 Padova, Italy;
Tel: +39 0498272715;
E-mail: carmelop87@hotmail.it

increases the flexibility of other points as well as of the entire chain [16-18]. This increase does not appear to depend on the specific treatment point since comparable results have been obtained by treating the point locally or by treating another point of the same chain [19, 20] or by local stretching [21]. Thus, it is evident that no matter where myofascial stretching or self-release is administered, this increased flexibility spreads throughout the chain with acute effects analogous to local stretching [22]. Furthermore, a recent review by Burk *et al*. (2019) identified 8 randomized trials including 354 participants, concluding that both myofascial techniques and stretching are associated with increased ROM in distant body segments [23]. It seems that the anatomical substrate that allows this transmission of force is represented by the fascia: *e.g*., a muscle contraction lengthens the relative myofascial expansions, transmitting part of muscular forces to the aponeurotic fascia [24]. In fact, as reported by Krause *et al*. (2016) [25] the underlying mechanism of force transmission could be related to the inherent structures of the fascial system itself, where a considerable variation in the amount of force transmission could be explained by discrepancy related to the conditions of tissue (*i.e*., hydration and temperature that influence its stiffness) as well as by the degree of morphological/anatomical continuity. However, the literature is still poor in data that clearly demonstrate whether the transmission of fascial forces follows specific myofascial lines and whether it is necessary to follow precise anatomical maps to have effects at one point in the chain. Thus, the present study aims to understand if the effect of an exercise at distance (*remote*) follows the course of the myofascial chain and whether stretching different muscle groups (hamstrings and adductors) gives the same effects at distance.

2. MATERIALS AND METHODS

Thirty healthy voluntary subjects aged between 19 and 32 years (mean age 24.1 ±4.13), 7 males and 23 females, height 166 ± 8 cm, BMI between 18 and 25.7 (mean 21.93 ± 3.50), randomly recruited by J.C. among the students of the motor science education course, were enrolled in the present study. All subjects were in good health and played sports at least twice a week. Exclusion criteria were musculoskeletal injuries in the past year, history of cervical and lumbar radicular pain, age less than 18 and greater than 32 years. All subjects provided their informed consent to inclusion prior to enrollment. The study was conducted in accordance with the Declaration of Helsinki, and all authors approved the protocol. All the following procedures (including protocol administration) have been performed by the same operator (J.C.). To assess maximal neck flexion, each subject was seated on a 44.5 cm high bench facing a wall. They must keep their feet on the floor aligned with the knee, their hands on their knees, their spine against the wall maintaining their physiological curves. The operator verified that the starting position was the same for all the subjects. The instrument used to measure cervical spine ROM was the HALO digital goniometer, model HG1 (HALO Medical Devices, Australia, https://halomedicaldevices.com Figure **1**). HALO has been scientifically validated for the measurement of cervical ROM [26, 27] and it is comparable to Zebris, the ultrasound analysis system used in Wilke's experiments mentioned in the introduction [28, 10]. The reliability and validity of HALO are excellent, all intra and interclass correlation coefficients are comparable to the gold standard and are greater than 0.75 [29]. Thus, the above-mentioned protractor was attached to the front of the subject using a band (Figure **1**).

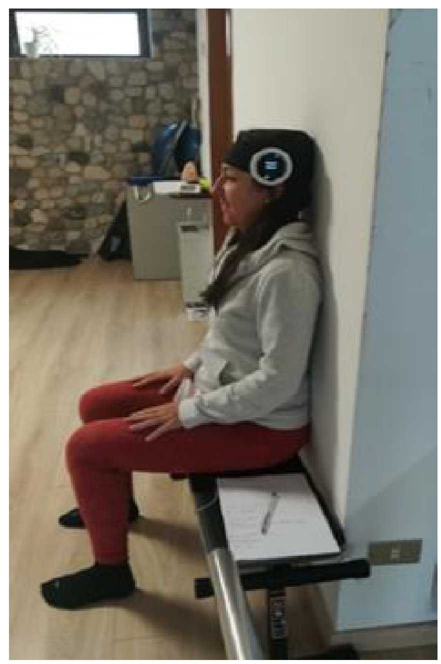


Figure 1: The subject is sitting on the bench with his back straight and close to the wall, and the digital protractor on the forehead in line with the reference point.

The protractor was positioned laterally above the ear and the laser always had to pass through a precise reference point: the ear's tragus. Each subject has one minute available to simulate the test (training phase); subsequently they performed five movements of maximum neck flexion which were recorded by the instrument (T_0). Then these five measurements were averaged to compare the results. To uniform the flexion movement of the neck, it was asked to flex the neck bringing the chin close to the chest, making the movement slow and controlled and keeping the back completely stable and close to the wall (Figure **2**).

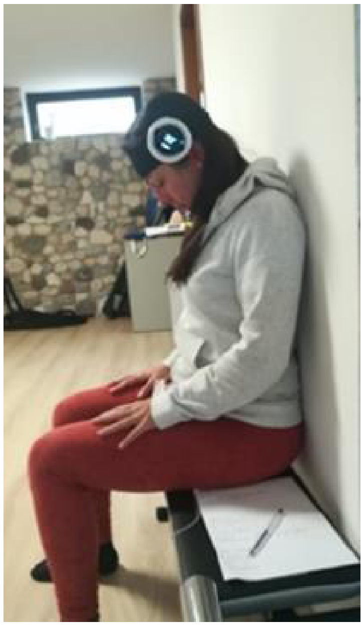


Figure 2: The subject is asked to flex the neck bringing the chin to the chest and keeping the back well against the wall.

Subsequently, the subject laid down on the floor on a mat and stretched the hamstring muscles in a supine position by lifting the leg whose foot was wrapped in a rope. The subject was asked to hold the rope and bring the leg to the chest keeping the knee straight and the pelvis in a neutral position, then to maintain the position for 30" on each leg 3 times, alternating the two legs. The leg on the ground was kept stretched out to optimize pelvic control while avoiding retroversion of the hips (Figure **3**).

Figure 3: Hamstrings stretch. The subject in the supine position lifts the lower limb, wraps it with a rope and brings the leg towards the chest to feel thetension on the hamstrings maintaining the posture for 30". The pelvis remains on the ground in a neutral position.

We selected these exercises because it is also used as a test to assess hamstrings flexibility [12, 17]. The subject should feel pain-free posterior thigh muscle tension. The subject was asked to maintain the position perceiving a medium intensity level of tension: level 2 of the Verbal Rating Scale (VRS) - where 0 corresponds to no intensity, 1 mild intensity, 2 moderate intensity, 3 strong intensity with trembling, 4 unbearable intensity [30]. No guidance was provided for the ankle joint other than keeping the foot relaxed. The instrument remained in the subject's forehead for the entire duration of the operation. At the end of the three stretching sessions, the five measurements of the cervical ROM in flexion were retested (T_1). Great care was taken to ensure that the protractor did not move from the reference point. After seven days, the initial ROM assessment of the neck was repeated (T_2). Next, each participant was asked to stretch the adductor muscles. Subject laid down on the floor on a mat facing a wall with feet against the wall and knees bent at 90°. The participant was asked to move the knees away from each other by bringing the feet into external rotation to feel the tension in the inner thigh muscles, but without feeling pain. The subject maintained the position for 1.5', perceiving the level 2 stretch intensity of the VRS scale (Figure **4**). At the end of the stretch time, the cervical flexion ROM was again measured (T_3). See sum up sessions' timetable in Table **1**.

Figure 4: Adductor stretching. The subject stands in front of the wall with the feet extra-rotated and the knees open to feel the tension in the adductor muscles. The participant maintained the position for 1.5'.

Table 1: Sum up Sessions' Timetable

Sessions	-	T_0	T_1	T_2	T_3
Timeline	**Day 1**			**After 7 days**	
Cervical ROM assessment	Training phase	At arrival	After hamstrings stretching	At arrival	After adductors stretching
Session content	Cervical flexion simulation	Cervical flexion (5 measurements)	Hamstrings stretching 3 times/leg + Cervical flexion (5 measurements)	Cervical flexion (5 measurements)	Adductors stretching (both legs) + Cervical flexion (5 measurements)
Session duration	60''	25''	30''(x3)/leg + 25''	25''	90'' + 25''

2.1. Statistical analysis

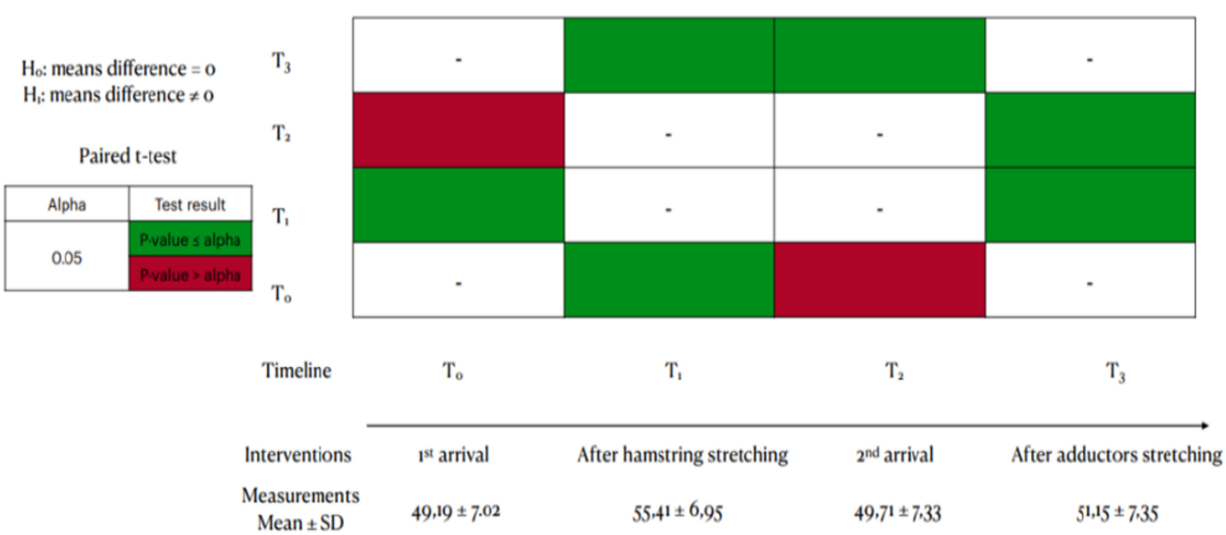
Data are presented as mean ± standard deviation (± SD). First, the distribution of data was checked, assuming a normal or approximately normal distribution by the central limit theorem (sample size=30). Data were analyzed using parametric statistics, after mathematical confirmation of a normal distribution using Shapiro-Wilks W test. Paired t-test (same group of subjects retested before/after treatment and after different treatments) was computed for the whole sample to assess the neck flexion difference after hamstrings and adductors stretching (95% for mean difference). Analyses were performed with Minitab software (State College, Pennsylvania 2010 Minitab, Inc), $p < 0.05$ was considered statistically significant.

3. RESULTS

At the end of each phase of the experiment we obtained these results: at T_0, the subjects presented a ROM of 49.19° ± 7.01°. At T_1, the subjects presented a ROM of 55.41° ± 6.95°. At T_2, the subjects presented a ROM of 49.71° ± 7.33°. At T_3, the subjects presented a ROM of 51.15° ± 7.35°. There is not a statistically significant difference between T_0 and T_2.

After stretching hamstrings (T_1), the ROM of the cervical spine significantly increases from 49.19° ± 7.01 ° to 55.41° ± 6.95° (+ 6.22°). After stretching the adductors (T_3) the ROM of the cervical spine significantly increases from 49.71° ± 7.33° to 51.15° ± 7.35 ° (+ 1.44°). Also comparing the ROM of the cervical spine after stretching the hamstrings and the adductors (55.41° ± 6.95° 51.15° ± 7.35°, respectively) a statistically significant increase was found, specifically with an increase of 4.26° greater after stretching the hamstrings. See Table **2** and diagram in Figure **5**.

Table 2: Comparison of the Neck Range of Motion at the Different Times



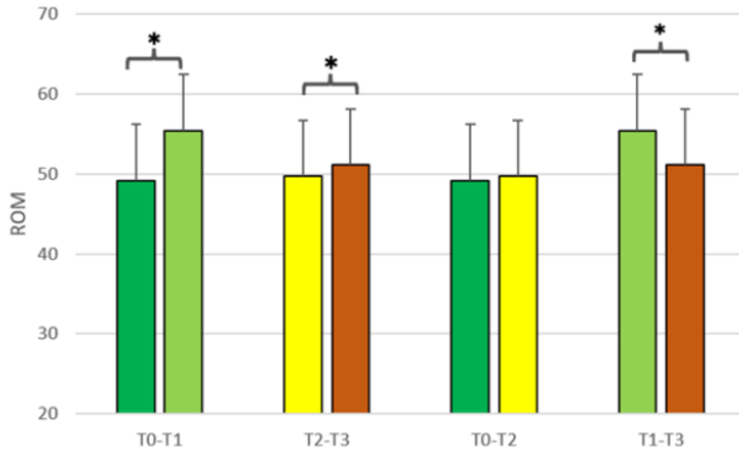


Figure 5: Range of motion of the Neck: comparisons among the different times.
*: statistically significant difference.

4. DISCUSSION

Our study, in agreement with literature [10, 11, 22], confirms that stretching of the lower limb increases the cervical ROM, but it adds further new information: it has demonstrated how this effect is transmitted along precise directions, and that not all the exercises have the same effectiveness at a distance. From our study, in fact, it is evident that the transfer of force exists in both stretching interventions, but the exercise carried out along the direction that follows the posterior myofascial line (that includes the hamstrings) is more effective than the one that follows the anterior line (that include the adductors); numerically, there was an increase in neck ROM of 6.22° for the hamstring muscles, compared to 1.44° for the adductor muscles. Even if the tensegrity model is often used to explain how fascia interconnects the different body segments, according to which bones do not have rigid connections to each other but they are supported by viscoelastic musculotendinous elements that provide a constant elastic tension within the system [31, 32], this concept implies that there are no precise directions in the transmission of force and that each part of the body can influence another area in the same way. Our results, on the contrary, have shown that there are precise lines in the body, and that the various segments are connected according to precise rules in terms of force transmission. Specifically, transmission of mechanical forces between components of myofascial chains occurs in the longitudinal (*e.g.*, proximo-distal) direction. The serial longitudinal arrangement of the components suggests a direct continuity between the head and the toes [33]. In this term, the posterior myofascial chain that connects the plantar aponeurosis →Achilles tendon→gastrocnemius muscle→hamstring muscles→sacrotuberous ligament → lumbar fascia → erector spinae muscles has been demonstrated to be more effective than the anterior one, which connects the adductors with the pyramidalis muscle, the rectus abdominis muscle and which follows the course of the abdominal linea alba, the sternal ligaments up to the neck. The connection between adductor and rectus abdominis was also reported by Wilke *et al*. (2016) [9] as playing a key role in groin pain or athletic pubalgia; while the abdominal linea alba and the sternal ligaments is well known to perform a more perceptive than motor function for the trunk. Since tissues' structure, arranged in a way that supports and optimizes the transmission of mechanical forces, the mobility of the human body during the activities of daily life strengthens the connections between the structures subjected to in-vivo loads. For the above, both the hamstrings and adductors have non-direct connections with the neck but in different ways also in terms of motricity.

Moreover, to understand the way each single structure (muscle, fascia, tendons) is involved in this force transmission, we considered a recent review [24] where the stress-strain values of muscles, tendons and fascia were compared. This analysis highlighted that during passive stretching the fascia is the first tissue that limits the stretch, suggesting that fascial tissue is probably the main target of static stretching [24], that absorbs and transmits the mechanical forces. Consequently, we can assume that it is the precise arrangement of the collagen fibers within the fasciae that defines the best direction for transmission of forces over a distance. Although fasciae are characterized by a multidirectional arrangement of collagen fibers, such arrangement follows precise directions in accordance with our daily living movements, *e.g.*, it is known that the crural fascia has an almost five times higher load capacity in the longitudinal direction than in the transverse direction [33, 31]. In fact, the flexor and extensor components of the neck have a strong, anatomical connection with the erector spinae and hamstrings compartments, up to the gastrocnemious muscles and crural fascia itself, as demonstrated by Wilke [33]. The latters could be further evidence that the potential transmission of mechanical forces through the fascia occurs mainly in the longitudinal direction. Therefore, we conclude that it is key to understand fascial anatomy and how fasciae are arranged to best interact with them through tailored interventions. This was the first study that attempted to compare different *remote* stretches according to myofascial lines. Further *in vivo* tests will be needed in the next future to confirm the way the effects of remote stretching affect the myofascial sequences to support this new therapeutic strategy. It will also be necessary to enlarge the sample size and integrate the analysis with additional investigation such as ultrasound imaging, to obtain more accurate and reliable results.

5. CONCLUSIONS

The present study confirms the existence of longitudinal myofascial chains (proximo-distal direction), reporting the effect of remote stretch (lower limbs) on cervical ROM. Furthermore, it demonstrates that the effectiveness of distance stretching varies according to the stretched structure, in our case adductors and hamstrings. From our data, it results that the stretching of the lower limbs increases the articular excursion of the cervical spine in flexion and that the transmission of forces follows precise directions (with preference of the posterior line), thus affecting the effectiveness of stretching interventions.

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