Journal of Sports Sciences

ISSN: 0264-0414 (Print) 1466-447X (Online) Journal homepage: https://www.tandfonline.com/loi/rjsp20

Is remote stretching based on myofascial chains as effective as local exercise? A randomised-controlled trial

J. Wilke, L. Vogt, D. Niederer & W. Banzer

To cite this article: J. Wilke, L. Vogt, D. Niederer & W. Banzer (2017) Is remote stretching based on myofascial chains as effective as local exercise? A randomised-controlled trial, Journal of Sports Sciences, 35:20, 2021-2027, DOI: 10.1080/02640414.2016.1251606

To link to this article: https://doi.org/10.1080/02640414.2016.1251606

JOURNAL OF SPORTS SCIENCES, 2017
VOL. 35, NO. 20, 2021–2027
https://doi.org/10.1080/02640414.2016.1251606

Is remote stretching based on myofascial chains as effective as local exercise? A randomised-controlled trial

J. Wilke, L. Vogt, D. Niederer and W. Banzer

Department of Sports Medicine, Goethe University Frankfurt am Main, Frankfurt am Main, Germany

ABSTRACT

Lower limb stretching based on myofascial chains has been demonstrated to increase cervical range of motion (ROM) in the sagittal plane. It is, however, unknown whether such remote exercise is as effective as local stretching. To resolve this research deficit, 63 healthy participants (36 ± 13 years, ♂32) were randomly assigned to one of three groups: remote stretching of the lower limb (LLS), local stretching of the cervical spine (CSS) or inactive control (CON). Prior (M1), immediately post (M2) and 5 min following intervention (M3), maximal cervical ROM was assessed. Non-parametric data analysis (Kruskal–Wallis tests and adjusted post hoc Dunn tests) revealed significant differences between the disposed conditions. With one exception (cervical spine rotation after CSS at M2, $P > .05$), both LLS and CSS increased cervical ROM compared to the control group in all movement planes and at all measurements ($P < .05$). Between LLS and CSS, no statistical differences were found ($P > .05$). Lower limb stretching based on myofascial chains induces similar acute improvements in cervical ROM as local exercise. Therapists might consequently consider its use in programme design. However, as the attained effects do not seem to be direction-specific, further research is warranted in order to provide evidence-based recommendations.

ARTICLE HISTORY
Accepted 14 October 2016

KEYWORDS
Myofascial chains; force transmission; fascia; meridians; MiSpEx

Introduction

Over decades, the skeletal muscles of the human body have been characterised as rather independent actuators. Recent research, however, has challenged this classical view. Fibrous connective tissues link the active components of the movement system creating an extensive network of myofascial chains (Wilke, Krause, Vogt, & Banzer, 2015). As experimental studies using cadavers (Norton-Old et al., 2013; van Wingerden, Vleeming, Snijders, & Stoeckart, 1993; Vleeming, Pool-Goudzwaard, Stoeckart, van Wingerden, & Snijders, 1995) demonstrated a mechanical force transmission along these connections, the effects of therapeutic interventions, e.g., stretching, might not be limited to the local area of application.

In a previous pilot study, we demonstrated that static stretching based on the course of the superficial back line (myofascial chain consisting of the plantar fascia, Achilles tendon, M. gastrocnemius, the hamstrings muscles, the sacrotuberous ligament and the lumbar fasciae/M. erector spinae) elicits remote flexibility effects: After stretching the calf and dorsal thigh muscles, cervical range of motion (ROM) in the sagittal plane was increased compared to an age- and sex-matched control group (Wilke, Niederer, Vogt, & Banzer, 2016). Although this finding provides first *in vivo* hints for a myofascial force transfer, the clinical relevance and the direction-specificity of the effects (concepts of myofascial chains claim a primarily longitudinal force transfer; Myers, 2012) have yet to be established in a randomised-controlled trial.

Building on the preliminary data from the pilot study, the objective pursued by the present trial therefore was to compare the acute effects of remote stretching based on the course of the superficial back line against local stretching exercises. We hypothesised that (1) both remote and local exercises improve cervical ROM more than no treatment, (2) local stretching is superior to remote stretching and (3) the largest stretch-induced increases occur in the sagittal plane as a sign of direction-specificity.

Methods

Study type and sample

Sixty-three healthy individuals participated in the three-armed randomised-controlled parallel group trial (Figure 1). Approval was obtained from the local ethics committee, and the study was conducted in accordance to the standards set by the declaration of Helsinki with its recent modification of Fortaleza. The trial was registered at clinicaltrials.gov (NCT02564081). All participants signed informed consent. Participants were recruited between April and September 2015 by use of posted flyers and personal contact. Exclusion criteria comprised (1) severe orthopaedic, cardiovascular, neurological, psychiatric or endocrine diseases; (2) permanent

CONTACT J. Wilke ✉ wilke@sport.uni-frankfurt.de Department of Sports Medicine, Goethe University Frankfurt am Main, Ginnheimer Landstraße 39 D-60487 Frankfurt am Main

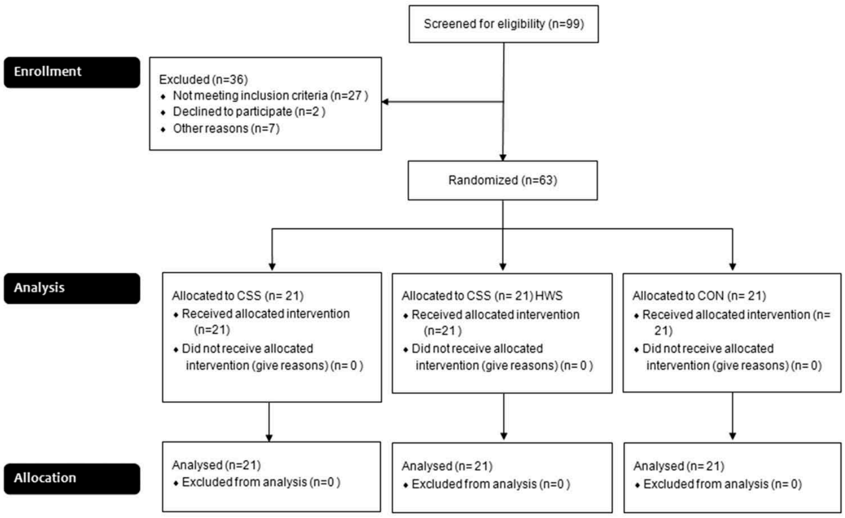

Figure 1. Flow chart of the trial.

drug intake or drug intake in past 48 h; (3) pregnancy or nursing period; and (4) presence of muscle soreness.

Randomisation

A complete randomisation was carried out by an independent investigator. All enrolled participants were allocated to three groups: lower limb stretching (LLS), cervical spine stretching (CSS) and inactive control (CON). To generate the randomisation list, an algorithm of BiAS for Windows (version 10, 2012, Goethe University Frankfurt am Main) was used.

Intervention

In accordance with the course of the superficial back line (Myers, 2001) and just like in the pilot study (Wilke et al., 2016), the participants of the LLS group bilaterally performed three consecutive 30 s bouts of static stretching for both the gastrocnemius muscle and the hamstrings respectively (Decoster, Cleland, Altieri, & Russell, 2005; Wilke et al., 2016). The treatment order was randomised with reference to body sides (left leg, right leg). Both stretching exercises were carried out standing (Figure 2) and held in a position of mild discomfort. In order to standardise the stretch, an intensity of 6–7 cm on a 10 cm visual analogue scale was targeted. Participants were instructed not to flex the spine and to maintain a neutral ankle position without activation of the M. tibialis anterior. Both criteria were visually monitored by an investigator.

In the CSS group, participants performed six 30 s bouts of static stretching for the neck extensors (Figure 2). Thus, net stretch exposure was identical to the LLS group. The exercises were carried out sitting with the back supported in a chair to

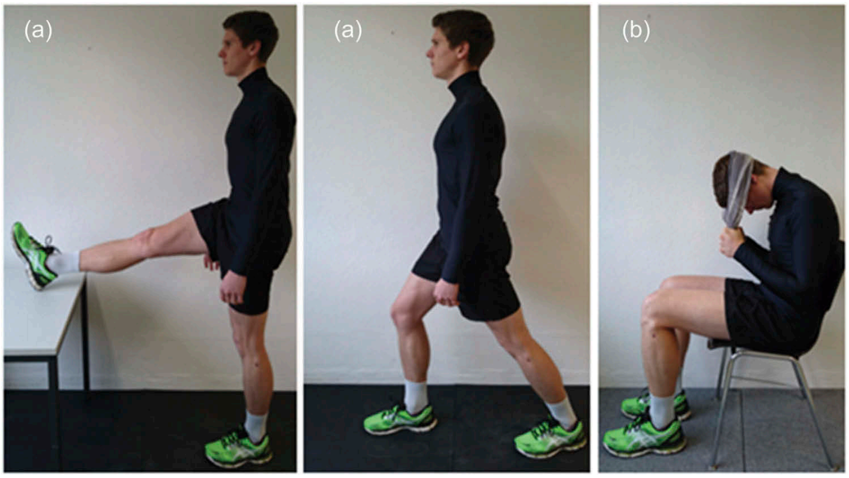

Figure 2. The stretching exercises of the LLS (a) and the CSS (b) group. Note that in order to select the appropriate stretch intensity, an adjustable table was used.

avoid compensatory movements of the spine. Analogous to the remote stretching exercises, targeted stretch intensity was 6–7 cm on a visual analogue scale.

In opposition to the two intervention groups, the participants of CON remained inactively seated for the duration of the stretching exercises.

Measurements

Outcome assessment was carried out at three points in time: prior (M1), immediately post (M2) as well as 5 min post intervention (M3). An ultrasonic 3D movement analysis system (Zebris CMS 70, Zebris Meditechnic GmbH, Isny, Germany, Figure 3) was used to capture maximal active cervical ROM. It exhibits excellent test–retest reliability (.86–.95; Williams, McCarthy, Chorti, Cooke, & Gates, 2010) and collects external kinematic data with an accuracy of >.6 mm (Himmelreich, Stefanicki, & Banzer, 1998) at a sampling rate of 30 Hz.

ROM of the cervical spine was measured in all three planes of movement. After three familiarisation trials, the participants, placed in a standardised sitting position, performed 10 self-paced maximal movement cycles in the sagittal plane (flexion-extension, Allison & Fukushima, 2003). Subsequently, the same procedure including familiarisation trials was applied for the transversal (rotation) and frontal (lateral flexion) plane. For all measurements, the participants were asked to report if pain or any other factor prevented them from attaining the maximal ROM.

Statistics

Non-parametric analyses were performed due to non-normal distribution of variables. Following omnibus testing (Kruskal–Wallis tests), systematic differences between the three disposed treatments were detected by means of post hoc Dunn tests with Sidak–Holm alpha-error-adjustment. Effect sizes for pairwise comparisons were calculated using the formula $r = z/\sqrt{n}$ (Fritz, Morris, & Richler, 2012). They were interpreted as small (<.3), moderate (.3 to .5) or large (>.5) (Cohen, 1988). The significance level was set at $\alpha = .05$. All analyses were run by an independent investigator; the employed software was SPSS version 22 (SPSS Inc., Chicago, USA).

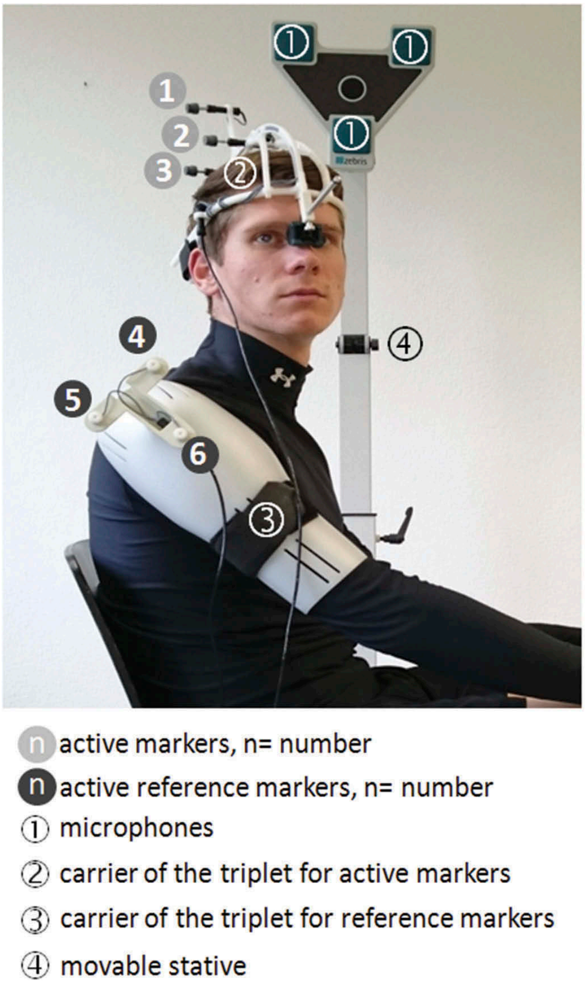

Figure 3. Schematic representation of the ultrasound-based cervical ROM measurement in the frontal plane.

Results

The groups did not differ regarding age, gender, body mass index (BMI) and baseline cervical ROM ($P > .05$, Table 1). Following

Table 1. Demographic, anthropometric and baseline data of the sample including variance analytical group comparisons and according *P*-values.

	Total sample	Local stretching	Remote stretching	Control	*P*- value
Age [years] Mean ± SD	36 ± 13	38 ± 13	38 ± 13	31 ± 13	.12
Gender *n*	♀31, ♂32	♀14, ♂7	♀9, ♂12	♀8, ♂13	.14
BMI [kg/m^{-2}] Mean ± SD	23.5 ± 4	22.8 ± 3	23.9 ± 4	23.8 ± 4	.54
Baseline ROM sagittal plane [°] Mean ± SD	141.8 ± 21	139.2 ± 24	139.8 ± 21	146.5 ± 18	.47
Baseline ROM transversal plane [°] Mean ± SD	165.9 ± 27	162.5 ± 24	167.2 ± 32	168.2 ± 26	.77
Baseline ROM frontal plane [°] Mean ± SD	88.0 ± 21	81.7 ± 18	88.3 ± 22	94.4 ± 23	.16

♀, female; ♂, male; BMI, body mass index; *n*, number; SD, standard deviation.

Table 2. Test values of global analysis (Kruskal–Wallis, left) and post hoc group comparisons (right) with relative changes [%] at the follow-up measurements immediately (M2) and 5 min (M3) post intervention.

	Kruskal–Wallis test criteria (*h* and *P*-values)	**CSS vs. CON** (difference [%], *P*-value, effect size)	**LLS vs. CON** (difference [%], *P*-value, effect size)	**CSS vs. LLS** (difference [%], *P*-value, effect size)
Sagittal plane (flexion-extension) *M2*	9.25 ($P = .01$)	+5 ($P = .02$) $r = .77$	+4 ($P = .03$) $r = .66$	+1 ($PP = .69$) $r = .11$
Sagittal plane (flexion-extension) *M3*	14.4 ($P = .001$)	+7 ($P = .001$) $r = .73$	+5 ($P = .001$) $r = .71$	+2 ($P = .93$) $r = .02$
Transversal plane (rotation) *M2*	8.2 ($P = .02$)	+5.5 ($P = .06$) $r = 48$	+3.5 ($P = .02$) $r = .62$	+2 ($P = .61$) $r = .12$
Transversal plane (rotation) *M3*	14.3 ($P = .001$)	+7 (P=.001) $r = .69$	+8 ($P = .001$) $r = .83$	−1 ($P = .84$) $r = .04$
Frontal plane (lateral flexion) *M2*	19.6 ($P = .001$)	+9 ($P = .001$) $r = .93$	+9 ($P = .001$) $r = .70$	0 ($P = .28$) $r = .24$
Frontal plane (lateral flexion) *M3*	14.5 ($P = .001$)	+7 ($P = .001$) $r = .77$	+6 ($P = .001$) $r = .66$	+1 ($P = .62$) $r = .11$

Displayed are median differences including *P*-values and effect sizes (*r*).
CSS, cervical spine stretching; CON, control; LLS, lower limb stretching.

intervention, data analyses revealed significant differences between the three conditions ($P < .05$, Table 2, Figure 4). Compared to CON, both LLS and CSS increased ROM in all examined movement planes and at each follow-up measurement ($P < .05$), with one exception: the increase of cervical spine rotation in CSS did not reach statistical significance at M2 (Table 2, Figure 4). No differences were found between LSS and CSS at any measurement ($P < .05$), and the effect sizes of the changes in comparison to CON were very similar in both groups (Table 2).

Discussion

To our knowledge, the present study was the first to compare the effects of local and remote stretching in a randomised-controlled *in vivo* setting. Verifying the primary hypothesis, it revealed that both strategies elicit considerable increases of cervical ROM. No differences were found between the two interventions. Consequently, our second hypothesis, which assumed local stretching to be more effective, has to be rejected. The observed non-inferiority of remote stretching endorses a more holistic view of athletes and patients as it seems viable to expand the focus of exercise design to multiple and distant body parts. Neck disorders can be associated with impaired ROM (Dall'Alba, Sterling, Treleaven, Edwards, & Jull, 2001; Vogt, Segieth, Banzer, & Himmelreich, 2007). LLS could therefore represent an interesting alternative to eliminate the restrictions if local treatments like manipulations are contraindicated.

The underlying causes of remote exercise effects remain controversial. One factor explaining non-local treatment reactions could consist in cortical adaptation processes. As different kinds of interventions (e.g., stretching, self-myofascial release and resistance training) have been demonstrated to affect both the involved and the uninvolved limb (Aboodarda, Spence, & Button, 2015; Chaouachi et al., 2015; Munn, Herbert, & Gandevia, 2004), it might be argued that exercise induces systemic responses like a reduced stretch tolerance. A second line of evidence suggests a mechanical force transmission via connective tissue to represent the driving factor. Biomechanical studies with cadavers have shown that fascial structures function to transfer strain to neighbouring skeletal muscles (Krause, Wilke, Vogt, & Banzer, 2016). In line with this, previous experimental research including the pilot trial of our workgroup (Carvalhais et al., 2013; Grieve et al., 2015; Wilke et al., 2016) has attributed its observations to the existence of myofascial chains. Finally, another theory assumes neural tissues to represent the substrate of the remote effects. Peripheral nerves cross multiple joints in a similar manner as myofascial chains do. Therefore, they might likewise act as a mechanical force transmitter. Changes of nerve tension have been observed in response to strain application (Kleinrensink, Stoeckart, Vleeming, Snijders, & Mulder, 1995; Lewis, Ramot, & Green, 1998). Nonetheless, Andrade, Lacourpaille, Freitas, McNair, and Nordez (2016) doubt a force transfer via neural tissue instead supposing a change in stretch tolerance.

Concerning the effects of the present study, among the mechanistic theories (connective vs. neural tissue), we consider a myofascial force transmission to be more likely owing to topographical reasons. In opposition to the superficial back line, peripheral nerves do not extend from the leg to the head. The sciatic nerve, which might have been stretched by the lower limb exercises, terminates in the lumbar spine (Franco, 2008). Although the occipital neck muscles display a structural connection to the dura mater (Hack, Koritzer, Robinson, Hallgren, & Greenman, 1995; Pontell, Scali, Marshall, & Enix, 2013), its practical significance is thought to mainly consist in supporting proprioception and preventing dural infolding (Kahkeshani & Ward, 2012). Hence, a purely mechanical force transmission from the lower leg to the neck via neural tissue seems unlikely.

Although all theories, the cortical and the mechanistic ones (be it via connective or neural tissue), seem credible, a direct proof has been provided for neither of them. In this sense, due to the lack of validated screening methods, most previous *in vivo* studies gathered indirect hints for the genesis of remote effects but failed to unravel their black box. Our study does not represent an exception to this. However, the direction-specificity of the attained remote effects provides valuable clues on their cause. Concepts of myofascial chains assume a primarily longitudinal (e.g., proximal-distal) force transfer which is plausible in view of the anisotropic alignment of the

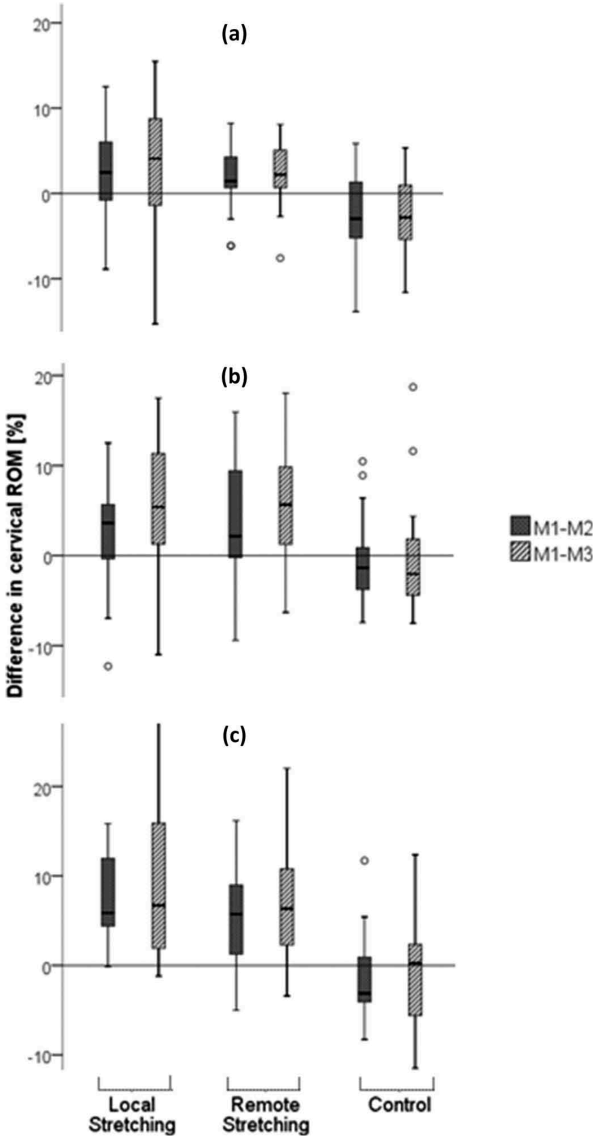

Figure 4. Box plots for the differences in cervical ROM induced by local stretching, remote stretching or inactivity: relative changes (M1 to M2 and M1 to M3) in the sagittal (a), transversal (b) and frontal plane (c). Each plot displays median, percentile 50 and range of data (whisker bars) including outliers. M, measurement time; ROM, range of motion.

collagen fibres and the three times higher stiffness of fasciae in longitudinal direction (Benetazzo et al., 2011; Eng, Pancheri, Lieberman, Biewener, & Dorfmann, 2014). Against this background, we expected the largest effects to occur in the sagittal cervical plane. In contrast to our third hypothesis, ROM increased to a similar extent in rotation and lateral flexion. A variety of explanations may account for the observation of direction-non-specific flexibility increases. For one thing, force transmission along myofascial chains might not exclusively occur longitudinally. Several studies have demonstrated the capability of fascia to transfer muscle force in transversal direction to synergists and antagonists (Huijing, Van De Langenberg, Meesters, & Baan, 2007; Maas, Baan, & Huijing, 2001; Maas, Meijer, & Huijing, 2005; Meijer, Rijkelijkhuizen, & Huijing, 2007). Such epimuscular force radiation effect might also happen to strain that has been transferred from remote body regions. In this case, force transfer along myofascial chains would have to be considered more as a global idea than as a direction-specific approach. For another thing, our findings must not necessarily contradict the principle of direction-specific force transfer. Most of the neck extensors, which bilaterally limit flexion of the cervical spine, act as lateral flexors when contracted unilaterally (Clarkson, 2000). Thus, the increases in side bending might be explainable. Similarly, although probably to a smaller extent, neck rotation is supported by some of the neck extensors (Clarkson, 2000). As, furthermore, rotational and side bending movements are coupled and inseparable (Bogduk & Mercer, 2000), the increases found in the transversal and frontal plane could also be attributed to a release of the neck extensors due to longitudinal strain transmission. An additional aspect supporting the idea of longitudinal strain transfer is that the hamstrings (part of the remote stretching intervention) do not only belong to the superficial back line, but also form part of the spiral line (another myofascial chain proposed by Myers, 2001). Cranially terminating with the M. splenius capitis (a rotator of the cervical spine, Sommerich, Joines, Hermans, & Moon, 2000), this pathway may have acted as an additional force transmitter.

Our trial has some shortcomings. As isolated lengthening of the left and right neck extensor muscles during cervical flexion is not possible, the CSS group stretched both of them simultaneously (3 × 30 s). In contrast, separate exercises were carried out in the LSS group (3 × 30 s per leg). Thus, while stretch time per muscle was identical, the total treatment time was shorter in CSS. Another issue relates to the assessment of cervical ROM. In the three movement planes, it was measured by means of combinatory movement cycles (e.g., left and right rotation of the cervical spine). Similar to the pilot study, this procedure was chosen because it provides more reliable data than separate measurements (Cagnie, Cools, Loose, De, Cambier, & Danneels, 2007). As in this way, delineating the relative contributions of neck flexion and extension is not possible, it, nonetheless, would have been interesting to quantify the changes in cervical flexion only. Also, data collection was performed non-invasively and without direct measurement of mechanical properties or simultaneous imaging. Consequently, as pointed out, unspecific neural contributions explaining the findings cannot be ruled out.

Several aspects call for further study. Identifying the causal mechanisms of remote exercise effects is paramount. Experiments combining different assessment methods might help to differentiate cortical and mechanical effects. Concerning the latter, the role of myofascial and neural tissues needs to be delineated. With reference to the experiment conducted in this study, it would be intriguing to investigate a potential reciprocity of the effects. While treatments of the lower limb seem to provoke remote effects in cranial direction (e.g., Grieve et al., 2015; Wilke et al., 2016), evidence is controversial with reference to projection in caudal direction. Andrade et al. (2016) did not observe a change in ankle ROM when flexing the cervical spine. In contrast, Montecinos-Cruz, Cerda, Sanzana-Cuche, Martin-Martin, and Cuesta-Vargas (2016) measured a displacement of the deep fascia surrounding the M. gastrocnemius during cervical flexion.

Another open question relates to the sustainability of the effects. In most cases, the increases in cervical ROM 5 min after stretching (M3) were even higher than immediately post treatment (M2). Also, in the local exercise group, the gains in rotational flexibility barely failed to reach statistical significance at M2 while being increased systematically at M3. Consequently, it might be that (1) the effects of local and remote stretching persist longer than a few minutes and (2) differences between both treatments occur in a larger time frame.

Conclusion

The present randomised-controlled trial yields three novel findings with implications for movement therapy. Firstly, it revealed that remote LLS is as effective as local neck stretching. Secondly and associated with this, it provides new evidence corroborating the idea of myofascial force transmission and more holistic treatment approaches. Finally, the results of the study raise the question whether remote exercise effects are direction-specific. Future research, in particular, should aim to pinpoint the importance of mechanical and cortical contributions within the occurrence of non-local treatment effects.

Acknowledgement

The authors thank Nadine Welpe for her assistance in data collection.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

The present study was initiated and funded by the Bundesinstitut für Sportwissenschaft and realized within MiSpEx – the National Research Network for Medicine in Spine Exercise [080102A/11-14].

References

Aboodarda, S. J., Spence, A. J., & Button, D. C. (2015). Pain pressure threshold of a muscle tender spot increases following local and non-local rolling massage. *BMC Musculoskel Disorders*, *16*. doi:10.1186/s1289170157072975

Allison, G. T., & Fukushima, S. (2003). Estimating three-dimensional spinal repositioning error: The impact of range, posture, and number of trials. *Spine*, *28*, 2510–2516. doi:10.1097/01.BRS.0000090821.38624.D5

Andrade, R. J., Lacourpaille, L., Freitas, S. R., McNair, P. J., & Nordez, A. (2016). Effects of hip and head position on ankle range of motion, ankle passive torque, and passive gastrocnemius tension. *Scandinavian Journal of Medicine & Science in Sports*, *26*, 41–47. doi:10.1111/sms.12406

Benetazzo, L., Bizzego, A., de Caro, R., Frigo, G., Guidolin, D., & Stecco, C. (2011). 3D reconstruction of the crural and thoracolumbar fasciae. *Surgical and Radiologic Anatomy*, *33*, 855–862. doi:10.1007/s0027670107075777

Bogduk, N., & Mercer, S. (2000). Biomechanics of the cervical spine. I: Normal kinematics. *Clinical Biomechanics*, *15*, 633–648. doi:10.1016/S026870033(00)0003476

Cagnie, B., Cools, A., Loose, V., de Cambier, D., & Danneels, L. (2007). Reliability and normative database of the zebris cervical range of motion system in healthy controls with preliminary validation in a group of patients with neck pain. *Journal Manipul Physiological Therap*, *30*, 450–455. doi:10.1016/j.jmpt.2007.05.003

Carvalhais, V. O. D. C., Ocarino, J. D. M., Araújo, V. L., Souza, T. R., Silva, P. L. P., & Fonseca, S. T. (2013). Myofascial force transmission between the latissimus dorsi and gluteus maximus muscles: An in vivo experiment. *Journal of Biomechanics*, *46*, 1003–1007. doi:10.1016/j.jbiomech.2012.11.044

Chaouachi, A., Padulo, J., Kasmi, S., Othmen, A. B., Chatra, M., & Behm, D. G. (2015). Unilateral static and dynamic hamstrings stretching increases contralateral hip flexion range of motion. *Clin Physiol Functional Imaging*, *n/a*. doi:10.1111/cpf.12263

Clarkson, H. M. (2000). *Musculoskeletal assessment: Joint range of motion and manual muscle strength* (2nd ed.). Philadelphia: Lippincott Williams & Wilkins.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: L. Erlbaum Associates.

Dall'Alba, P. T., Sterling, M. M., Treleaven, J. M., Edwards, S. L., & Jull, G. A. (2001). Cervical range of motion discriminates between asymptomatic persons and those with whiplash. *Spine*, *26*, 2090–2094. doi:10.1097/00007632-200110010-00009

Decoster, L. C., Cleland, J., Altieri, C., & Russell, P. (2005). The effects of hamstring stretching on range of motion: A systematic literature review. *The Journal of Orthopaedic and Sports Physical Therapy*, *35*, 377–387. doi:10.2519/jospt.2005.35.6.377

Eng, C. M., Pancheri, F. Q., Lieberman, D. E., Biewener, A. A., & Dorfmann, L. (2014). Directional Differences in the Biaxial Material Properties of Fascia Lata and the Implications for Fascia Function. *Annals of Biomedical Engineering*, *42*, 1224–1237. doi:10.1007/s10439-014-0999-3

Franco, C. D. (2008). Applied anatomy of the lower extremity. *Techniques in Regional Anesthesia & Pain Management*, *12*, 140–145. doi:10.1053/j.trap.2008.02.003

Fritz, C. O., Morris, P. E., & Richler, J. J. (2012). Effect size estimates: Current use, calculations, and interpretation. *The Journal of Experimental Psychology*, *141*, 2–18. doi:10.1037/a0024338

Grieve, R., Goodwin, F., Alfaki, M., Bourton, A. J., Jeffries, C., & Scott, H. (2015). The immediate effect of bilateral self myofascial release on the plantar surface of the feet on hamstring and lumbar spine flexibility: A pilot randomised controlled trial. *Journal of Bodywork and Movement Therapies*, *19*, 544–552. doi:10.1016/j.jbmt.2014.12.004

Hack, G. D., Koritzer, R. T., Robinson, W. L., Hallgren, R. C., & Greenman, P. E. (1995). Anatomic relation between the rectus capitis posterior minor muscle and the dura mater. *Spine*, *20*, 2484–2485. doi:10.1097/00007632-199512000-00003

Himmelreich, H., Stefanicki, E., & Banzer, W. (1998). Ultrasound controlled anthropometry on the development of a new method in asymmetry diagnosis. *Sportverl Sportscha*, *12*, 60–65. doi:10.1055/s720077993339

Huijing, P. A., van de Langenberg, R. W., Meesters, J. J., & Baan, G. C. (2007). Extramuscular myofascial force transmission also occurs between synergistic muscles and antagonistic muscles. *Journal of Electromyography and Kinesiology*, *17*, 680–689. doi:10.1016/j.jelekin.2007.02.005

Kahkeshani, K., & Ward, P. J. (2012). Connection between the spinal dura mater and suboccipital musculature: Evidence for the myodural bridge and a route for its dissection. A review. *Clinical Anatomy*, *25*, 415–422. doi:10.1002/ca.21261

Kleinrensink, G. J., Stoeckart, R., Vleeming, A., Snijders, C. J., & Mulder, P. G. (1995). Mechanical tension in the median nerve. The effects of joint positions. *Clinical Biomechanics*, *10*, 240–244. doi:10.1016/026870033(95)9980178

Krause, F., Wilke, J., Vogt, L., & Banzer, W. (2016). Intermuscular force transmission along myofascial chains: A systematic review. *Journal of Anatomy*, *228*, 910–918. doi:10.1111/joa.12464

Lewis, J., Ramot, R., & Green, A. (1998). Changes in Mechanical Tension in the Median Nerve: Possible implications for the upper limb tension test. *Physiotherapy*, *334*, 254–261. doi:10.1016/S003179406(05)6552471

Maas, H., Baan, G. C., & Huijing, P. A. (2001). Intermuscular interaction via myofascial force transmission: Effects of tibialis anterior and extensor hallucis longus length on force transmission from rat extensor digitorum longus muscle. *Journal of Biomechanics*, *34*(7), 927–940. doi:10.1016/S0021-9290(01)00055-0

Maas, H., Meijer, H. J. M., & Huijing, P. A. (2005). Intermuscular interaction between synergists in rat originates from both intermuscular and extramuscular myofascial force transmission. *Cells, Tissues, Organs*, *181*, 38–50. doi:10.1159/000089967

Meijer, H. J. M., Rijkelijkhuizen, J. M., & Huijing, P. A. (2007). Myofascial force transmission between antagonistic rat lower limb muscles: Effects of single muscle or muscle group lengthening. *Journal of Electromyography and Kinesiology*, *17*, 698–707. doi:10.1016/j.jelekin.2007.02.006

Montecinos-Cruz, C., Cerda, M., Sanzana-Cuche, R., Martin-Martin, J., & Cuesta-Vargas, A. (2016). Ultrasound assessment of fascial connectivity in the lower limb during maximal cervical flexion: Technical aspects and practical application of automatic tracking. *BMC Sports Science, Medicine and Rehabilitation*, *epub*. doi:10.1186/s13102-016-0043-z

Munn, J., Herbert, R. D., & Gandevia, S. C. (2004). Contralateral effects of unilateral resistance training: A meta-analysis. *Journal of Applied Physiology*, *96*(5), 1861–1866. doi:10.1152/japplphysiol.00541.2003

Myers, T. W. (2001). *Anatomy trains: Myofascial meridians for manual and movement therapists*. Edinburgh, NY: Churchill Livingstone.

Myers, T. W. (2012). Anatomy trains and force transmission. In R. Schleip, T. W. Findley, L. Chaitow, & P. A. Huijing (Eds.), *Fascia: The tensional network of the human body* (pp. 131–135). London: Churchill Livingstone.

Norton-Old, K. J., Schache, A. G., Barker, P. J., Clark, R. A., Harrison, S. M., & Briggs, C. A. (2013). Anatomical and mechanical relationship between the proximal attachment of adductor longus and the distal rectus sheath. *Clinical Anatomy*, *26*, 522–530. doi:10.1002/ca.22116

Pontell, M. E., Scali, F., Marshall, E., & Enix, D. (2013). The obliquus capitis inferior myodural bridge. *Clinical Anatomy*, *26*, 450–454. doi:10.1002/ca.22134

Sommerich, C. M., Joines, S. M., Hermans, V., & Moon, S. D. (2000). Use of surface electromyography to estimate neck muscle activity. *Journal of Electromyography and Kinesiology*, *10*, 377–398. doi:10.1016/S105076411(00)000337X

van Wingerden, J. P., Vleeming, A., Snijders, C. J., & Stoeckart, R. (1993). A functional-anatomical approach to the spine-pelvis mechanism: Interaction between the biceps femoris muscle and the sacrotuberous ligament. *European Spine Journal*, *2*, 140–144. doi:10.1007/BF00301411

Vleeming, A., Pool-Goudzwaard, A. L., Stoeckart, R., van Wingerden, J. P., & Snijders, C. J. (1995). The posterior layer of the thoracolumbar fascia. Its function in load transfer from spine to legs. *Spine*, *20*(7), 753–758. doi:10.1097/00007632-199504000-00001

Vogt, L., Segieth, C., Banzer, W., & Himmelreich, H. (2007). Movement behaviour in patients with chronic neck pain. *Physiotherapy Research International*, *12*, 206–212. doi:10.1002/pri.377

Wilke, J., Krause, F., Vogt, L., & Banzer, W. (2015). What is evidence-based about myofascial chains: A systematic review. *Archives of Physical Medicine and Rehabilitation*. doi:10.1016/j.apmr.2015.07.023

Wilke, J., Niederer, D., Vogt, L., & Banzer, W. (2016). Remote effects of lower limb stretching: Evidence for myofascial connectivity?. *Journal Sport Sciences [In Production]*. doi:10.1080/02640414.2016.1179776

Williams, M. A., McCarthy, C. J., Chorti, A., Cooke, M. W., & Gates, S. (2010). A systematic review of reliability and validity studies of methods for measuring active and passive cervical range of motion. *Journal Manipul Physiological Therap*, *33*, 138–380. doi:10.1016/j.jmpt.2009.12.009