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Article

Influence of Rolfing Structural Integration on Active Range of Motion. A Retrospective Cohort Study.

Andreas Brandl [1,2,3], Katja Bartsch [4], Helen James [5], Marilyn E. Miller [6], Robert Schleip [2,7,*]

1 Department of Sports Medicine, Faculty for Psychology and Human Movement Science, Institute for Human Movement Science, University of Hamburg, 20148 Hamburg, Germany; andreas.brandl@edu.ioesr.org
2 DIPLOMA Hochschule, 37242 Bad Sooden-Allendorf, Germany
3 Osteopathic Research Institute, Osteopathie Schule Deutschland, 22297 Hamburg, Germany;
4 Department of Sport Science and Sports, Friedrich-Alexander University Erlangen-Nürnberg, 91058 Erlangen, Germany; katja.kb.bartsch@fau.de
5 Department of Physical Therapy, California State University, Fresno, USA; helenj@cvip.net
6 Department of Physical Therapy, University of St. Augustine for Health Sciences at San Diego, San Diego, USA; mem@cox.net
7 Conservative and Rehabilitative Orthopedics, Department of Sport and Health Sciences, Technical University of Munich, 80333 Munich, Germany; robert.schleip@tum.de
* Correspondence: robert.schleip@tum.de; Tel.: +49-89-289-24561

Abstract: Background: Recent work has investigated significant force transmission between the components of myofascial chains. Misalignments in the body due to fascial thickening and shortening can therefore lead to complex compensatory patterns. For the treatment of such nonlinear cause-effect pathology, a comprehensive neuro-musculoskeletal therapy such as the Rolf Method of Structural Integration (SI) could be targeted. Methods: A total of 727 subjects were retrospectively screened from the medical records of an SI practice over a 23-year period. 383 subjects who had completed 10 basic SI sessions met eligibility criteria and were assessed for active range of motion (AROM) of the shoulder and hip before and after SI treatment. Results: Shoulder flexion, external and internal rotation, and hip flexion improved significantly (all $p < 0.0001$) after 10 SI sessions. Left shoulder flexion and external rotation of both shoulders increased more in men than in women ($p < 0.0001$), but were not affected by age. Conclusions: SI intervention produces multiple changes in the components of myofascial chains that could help maintain upright posture in humans and reduce inadequate compensatory patterns. SI affects differently the outcome of some AROM parameters in women and men.

Keywords: active range of motion; Structural Integration; Rolfing; fascia

1. Introduction

For many decades, the connective tissue respectively the fascia was seen only as a packaging organ without any active influence on the maintenance of the human posture [1]. However, research on this topic over the past 20 years paints a different picture. Schleip et al. [2] discovered active contractile properties of some fascial tissues (e.g., thoracolumbar fascia, gastrocnemius fascia, and fascia lata) that are likely mediated by the sympathetic nervous system. Another mechanism for altering the viscoelastic behavior of such tissues is the ability to change their water content [3]. This offers the possibility of softening or hardening the fascia in the long term and even in the short term (within minutes) depending on various neural or mechanical stimuli. Recent work has led to the knowledge that fascia is an organ that connects rather than separates skeletal muscles [4,5]. Wilke et al. [6] have shown that a force can be transmitted through a sufficiently stiff fascial connection between serially connected skeletal muscles. Therefore, collagenous connective

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tissue may play an important role in maintaining human upright posture. We can hypothesize that misalignments in the body due to fascial thickening and shortening can lead to complex compensatory patterns, musculoskeletal disorders, and pain.

The Rolf Method of Structural Integration (SI) is a comprehensive "whole body" approach to fascia therapy with elements of sensorimotor education. It focuses on balancing posture by teaching the body to move in a way that is more effective by helping to release strain and stiffness [7]. SI practitioners apply a series of 10 sessions of fascial manipulation techniques. This approach consists of an individualized course in each session with specific mechanotransductive and sensorimotor goals (for an individual description of the sessions see e.g. Kasper-Jedrzejewska et al., 2020 [8] or Jacobson, 2011 [9]). The main goal is to achieve balance in posture by changing individual parts that affect the person in the field of gravity, improving the ergonomics of movement and relieving patient discomfort [10]. The pressure applied by the therapist targets to loosen the adhesions between the fascia layers and restore their gliding abilities. The aim of the procedure is that contractures, which do not necessarily have to be permanent changes, can be rearranged so that the collagen fibers can move again [11]. These improvements in the structure of the human body are considered to correlate directly with physiological improvements. In addition, fascia adapts to physical stress, so when manual therapy techniques press on fascia, they may alter its density, tone, or organization [7,12].

Given the goals of SI and its hypothesized effects on the fascial system, SI can result in significant improvement in the active range of motion (AROM) of body joints in patients suffering from connective tissue contractions. James et al. [10] conducted a retrospective study examining the impact of SI on AROM of the cervical spine and showed that SI can result in a significant decrease in pain and increase in AROM in these structures when used by a physical therapist with advanced SI certification. For this study, the medical records of a local physical therapy practice for cervical AROM and pain data were analyzed.

In this work, these records were secondarily analyzed to extract AROM data for the shoulder and hip. The purpose of this analysis is to provide comprehensive information on the impact of SI on the AROM of patients in the specific health care setting over a representative period of 23 years of treatment of a private practice.

2. Materials and Methods

A secondary analysis of the study data from James et al. [10] was performed. A total of 727 records of subjects were available from the medical records of a local physical therapy practice. Collectively, these subjects were treated by a physical therapist who was also an advanced SI practitioner and a professor emeritus in the Department of Physical Therapy at California State University, Fresno. These prospective subjects were studied between February 7, 1982, and November 18, 2005. All the subjects were given informed consent and the protocols were approved by the East Orange Department of Veterans Affairs (VA) Medical Center International Review Board (IRB) and the University of Medicine and Dentistry of New Jersey-Newark IRB. All data were coded anonymously in an Excel spreadsheet (Office 2019, Microsoft Corporation, USA), so that investigators could not identify individuals.

2.1. Eligibility criteria

Eligibility criteria were (a) completion of all 10 SI sessions; (b) male or female subjects aged 18 to 60 years; (c) a body mass index (BMI) between 19 and 29 [13]; (d) availability of either shoulder flexion, external rotation, and internal rotation data or hip flexion, side bend (SBN), and finger-floor distance (FFD) data. Subjects without anamnestically reported medical conditions were excluded.

2.2. Outcomes

Subjects were assessed for complaints related to back, neck, and other pain syndromes or combinations of such syndromes. AROM measurements were taken during the

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initial (before the start of SI treatment sessions) and final (after 10 SI sessions) assessments. Clinical data collected included: age, sex, dates of initial and final assessments, complaints before, during, and after SI, diagnosis, height, weight, and AROM. Data were collected during the initial assessment by a physical therapist with more than 20 years of experience in AROM measurement and provide the basis for determining subjects' functional limitations, interventions, and outcomes.

All AROM measurements except for SBN and FFD were performed with the patient supine using a 12-inch 360° goniometer, labeled in 1° increments, with two adjustable overlapping arms.

2.2.1. AROM of the shoulder

Shoulder flexion ROM was measured by instructing the patient to raise their arm straight above their head as far as possible. The stationary arm was positioned parallel to the midline of the rib cage, while the movable arm was aligned with the shaft of the humerus and the lateral epicondyle [14].

External rotation of the shoulder was measured by passively placing the patient's arm in 90° abduction with the elbow flexed at 90° and instructing the patient to rotate the arm as far back as possible with the palm pointing toward the ceiling. Goniometric standard positioning was used by placing the stationary arm perpendicular to the floor and aligning the moving arm with the shaft of the ulna and the styloid process [14].

Internal rotation of the shoulder was measured by passively placing the patient's arm in 90° abduction with the elbow flexed at 90° and instructing the patient to rotate his or her arm forward as far as possible so that the palm was pointing toward the floor. Goniometer positioning for measurement was also performed in a standardized manner [14].

The intrarater reliability of the aforementioned parameters of the AROM Shoulder measurement was reported to be excellent (ICC = 0.91 to 0.99) [15].

2.2.2. AROM of the hip

Hip flexion ROM was measured by instructing the subject to keep the contralateral distal thigh stable toward the treatment bench and to avoid pelvic motion during the test. The participant was then asked to flex the hip with the knee in flexion until they felt a firm end sensation or pain restriction that prevented further movement. The examiner then aligned the axis of the goniometer with the greater trochanter and the arms with the lateral condyle of the thigh and the midaxillary line. When the trunk and thigh were parallel, hip flexion AROM was defined as 0° (Figure 1). Subjects held their hands across the chest during the test. Intrarater reliability in measuring hip joint range of motion was reported to be good (ICC = 0.75) [16].

Figure 1. Hip flexion measurement.

2.2.3. Side bend

To evaluate trunk movement during lateral bending, the subject stood upright on the floor, heels together, knees straight and arms in a neutral position. The subject was asked to bend to the side with arms hanging as far as possible while keeping the fingers straight. Then the distance between the tip of the right or left 3rd finger and the floor was measured with a ruler. The reliability coefficients for these measurements were reported to be large (r = 0.91) [17].

2.2.3. Finger to floor distance

The distance between the fingers and the floor was also measured while the subject stood upright on the floor, heels together, knees extended and arms in a neutral position. The subject was asked to bend forward as far as possible while keeping the knees and fingers straight. Then, the distance between the tip of the right 3rd finger and the floor was measured with a ruler. The reliability coefficients for these measurements were reported to be high (r = 0.98) [17].

2.3. Statistical Analyses

The standard deviation (SD), mean, and 95% confidence interval (95% CI) were determined for all parameters. Outliers above 1.5 times the interquartile range of the third quartile or below this factor of the first quartile were excluded from the analysis. Variables that did not meet the assumptions of normal distribution according to the Kolmogorov-Smirnov test ($p < 0.05$) or violated homogeneity of error variances between groups according to Levene's test ($p < 0.05$) were Box-cox transformed. A four-way ANOVA with the factors: Structural Integration (SI) treatment (before and after), sex (female and male), age group (younger and older or equal to the median age), and illness (back pain, neck pain, shoulder pain, combined, and other) was used to test the hypotheses. Significant interaction effects were assessed using the Tukey HSD post-hoc test analysis. The significance level was set at $p = 0.05$.

Libreoffice Calc version 6.4.7.2 (Mozilla Public License v2.0) was used for the descriptive statistics. The inferential statistics were carried out with the software R, version 3.4.1 (R Foundation for Statis-tical Computing, Vienna, Austria).

3. Results

The anthropometric data and baseline characteristics are shown in Table 1. Of 727 subjects treated between 07/02/1982 and 18/11/2005, 383 met eligibility criteria and were analyzed (Figure 1). The median age was 39.8 years.

Table 1. Baseline characteristics

Baseline characteristics	Participants (n=383) mean ± SD
Gender (men / woman)	154 / 228
Disease (A / B / C / D / E)	101 / 114 / 42 / 27 / 99
Age (years)	39.0 ± 11.1
Age group (younger / older)	189 / 194
Height(m)	1.70 ± 0 .1
Weight (kg)	71.3 ± 16.1
BMI (kg/m^2)	25.2 ± 5.7

SD, standard deviation; n, number; Disease A, other; B, back pain; C, neck pain; D, shoulder pain; E, combined A to D.

For all outcomes, there was no four-way interaction between SI treatment, gender, age group, and disease. There was no three-way interaction between SI treatment, gender, and age group; SI treatment, gender, and disease; or SI treatment, age group, and disease.

The four-way ANOVA revealed a significant two-way interaction between SI treatment and gender for left shoulder flexion ($F[1, 418] = 8.97$, $p = 0.003$, partial $\eta^2 = 0.020$), but not for right ($F[1, 416] = 2.96$, $p < 0.086$, partial $\eta^2 = 0.007$). There was also a significant interaction between SI treatment and sex for left shoulder extension ($F[1, 386] = 10.63$, $p = 0.001$, partial $\eta^2 = 0.027$), but not for right ($F[1, 440] = 1.05$, $p < 0.305$, partial $\eta^2 = 0.002$). A post-hoc Tukey HSD test was performed for these interactions. The results of the post-hoc analysis and the simple main effects are shown in Table 2.

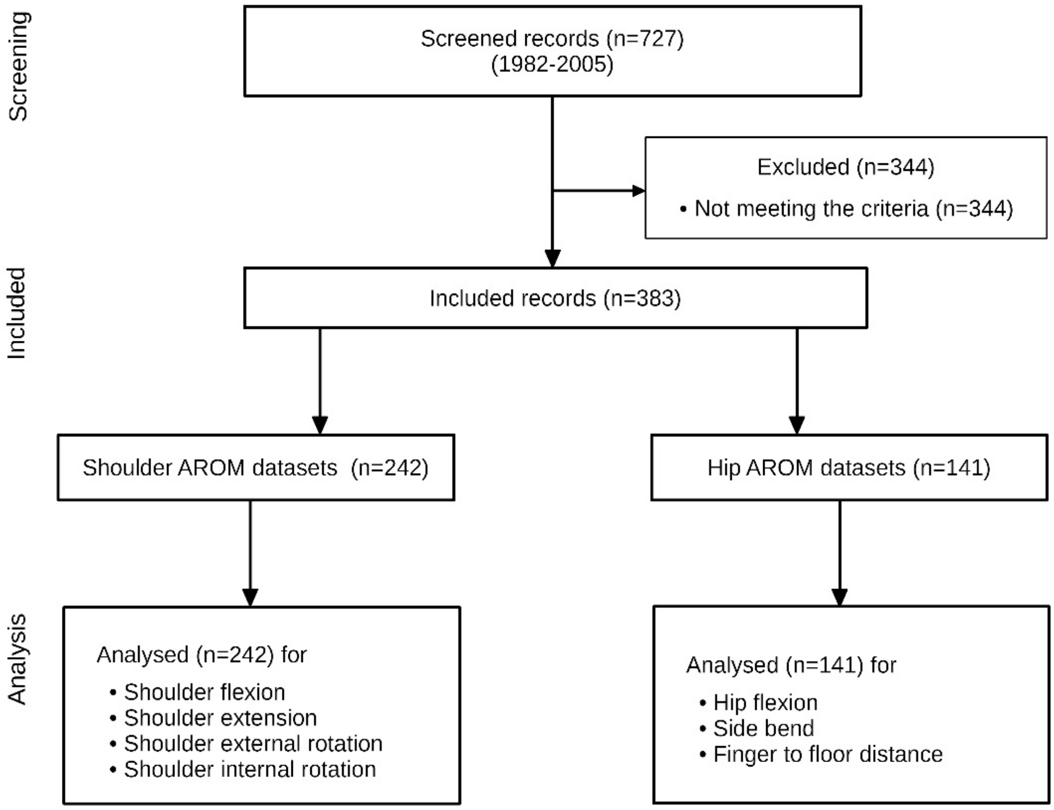

Figure 3. Flow chart of the study.

The changes between the baseline measurement, and the measurement after treatment is shown in Figure 2.

4. Discussion

This secondary analysis of the study data by James et al. [10] aimed to provide comprehensive information on the impact of SI on patients' shoulder and hip AROM. This retrospective study, along with the work of James et al. [10] was the first to examine SI in 727 subjects in the specific health care setting of a private practice over a representative 23-year period.

4.1 AROM of the shoulder

The main results showed that all measured AROM parameters of the shoulder were significantly increased after SI treatment. Flexion and external rotation showed a significant interaction between gender and treatment. It is noteworthy at this point that AROM increased much more for men than for women for the left shoulder (e.g., +187% vs. +79% for left shoulder external rotation). It is well known that myofascial stiffness is higher in men than in women [18]. A recent study by Bohlen et al. [19] found increased efficacy of more force-intensive manual therapy techniques on muscle tone at rest in men than in women. There is also evidence of higher lumbar myofascial stiffness on the dominant side of the body [20,21]. Data on hand dominance were not available in this study. However,

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it can be assumed that most participants were right-handed, as only 10% of people have left hand dominance [22]. Considering the stiffness of thoracolumbar fascia (TLF) and its ability to transfer force from the right to the left side of the body [23–25], SI-induced reduction in TLF stiffness could lead to improvement in left shoulder AROM in addition to local mechanisms.

Table 2. Descriptive statistics and ANOVA

	All subjects (n=383)										
	Shoulder (n=242)						**Hip (n=141)**				
	Flexion L	**Flexion R**	**External rotation L**	**External rotation R**	**Internal rotation L**	**Internal rotation R**	**Flexion L**	**Flexion R**	**Side bend L**	**Side bend R**	**Finger to floor**
ΔMean	7.81°	7.16°	4.26°	4.52°	18.00°	17.33°	8.30°	8.26°	0.42 cm	0.68 cm	-2.21 cm
SD	12.87	10.83	9.06	10.61	13.13	10.87	8.84	8.70	1.61	1.77	6.73
95%-CI	5.17 – 10.6	4.62 – 9.70	2.61 – 5.92	2.22 – 6.22	15.5 – 20.5	14.9 – 19.8	6.12 – 10.8	6.14 – 10.9	-0.33 – 1.17	-0.07 – 1.42	-4.51 – 0.09
% t_1-t_0	+5%	+4%	+5%	+5%	+37%	+38%	+7%	+7%	+1%	+2%	-25%
ANOVA[1]											
DFn, DFd	1,418	1,416	1,386	1,386	1,440	1,440	1,238	1,242	1,242	1,244	1,230
F	70.80	57.26	70.80	32.81	207.7	189.3	56.41	57.48	1.56	3.75	3.02
η^2	0.15	0.12	0.08	0.08	0.32	0.30	0.19	0.19	0.006	0.015	0.013
p	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.213	0.054	0.084
	Female (n=228)										
	Shoulder (n=147)						**Hip (n=81)**				
	Flexion L	**Flexion R**	**External rotation L**	**External rotation R**	**Internal rotation L**	**Internal rotation R**	**Flexion L**	**Flexion R**	**Side bend L**	**Side bend R**	**Finger to floor**
ΔMean	5.48°	6.19°	2.46°	3.45°	16.97°	16.64°	8.70°	8.21°	0.43 cm	0.67 cm	-1.93 cm
SD	14.34	11.29	7.34	10.59	13.69	10.46	8.76	8.11	1.60	1.79	6.82
95%-CI	1.04 – 9.91	1.92 – 10.5	-0.34 – 5.25	0.62 – 6.32	12.8 – 21.1	12.5 – 20.8	4.94 – 12.5	4.54 – 11.9	-0.84 – 1.69	-0.61 – 1.95	-5.91 – 2.06
p (adjusted)[2]	0.008		0.158	0.112							
	Male (n=154)										
	Shoulder (n=95)						**Hip (n=59)**				
	Flexion L	**Flexion R**	**External rotation L**	**External rotation R**	**Internal rotation L**	**Internal rotation R**	**Flexion L**	**Flexion R**	**Side bend L**	**Side bend R**	**Finger to floor**
ΔMean	11.42°	8.65°	7.06°	6.16°	19.58°	18.40°	7.75°	8.33°	0.42 cm	0.69 cm	-2.59 cm
SD	9.16	9.94	10.66	11.31	12.13	11.46	8.99	9.51	1.64	1.77	6.65
95%-CI	5.90 – 16.94	3.33 – 14.0	3.59 – 10.5	2.61 – 9.70	14.4 – 24.7	13.3 – 23.6	3.38 – 12.1	4.07 – 12.6	-1.05 – 1.89	-0.82 – 2.19	-7.22 – 2.04
% m-f	+108%	+40%	+187%	+79%	+15%	+11%	-11%	+1%	-2%	+3%	+34%
p (adjusted)[2]	< 0.0001		< 0.0001	< 0.0001							

ΔMean, mean difference bevor and after Rolfing Structural Integration treatment; SD, standard deviation; n, number; 95%-CI, 95% confidence interval; % t_1-t_0, percentage difference between baseline and after treatment; % m-f, percentage difference between men and women; DFn, degree of freedom for the numerator; DFd, degree of freedom for the denominator; p, p-Value; L, left; R, right. [1] simple main effect of Rolfing Structural Integration treatment. [2] adjusted p from Tukey HSD test for significant treatment/gender interactions.

The movement in the shoulder that improved the most was internal rotation. An amelioration of 17° to 18° was achieved, corresponding to an increase of 37-38% when compared before and after SI treatment. James et al. [10], referring to the same data, reported the highest increase in motion in lateral neck flexion (32%). One muscle that is highly involved in both movements is the trapezius muscle [26]. Although both functions are influenced to varying degrees by different parts of this muscle, it is likely that SI improved the functionality of the trapezius, which could lead to an enhancement of both AROM parameters.

4.2 AROM of the hip

For hip (and trunk) mobility, the results showed a significant improvement in flexion AROM of both hip joints (+7%). No interaction was found between gender and treatment. This was surprising, as there were such interactions in some shoulder parameters, indicating different efficacy of SI treatment in men and women. Considering the gender differences in response to manual therapy techniques and TLF stiffness, one might expect the results to be similar in the hip and shoulder [18,19].Future research focusing on the gender-specific efficacy of SI is needed to uncover further associations of these mechanisms.

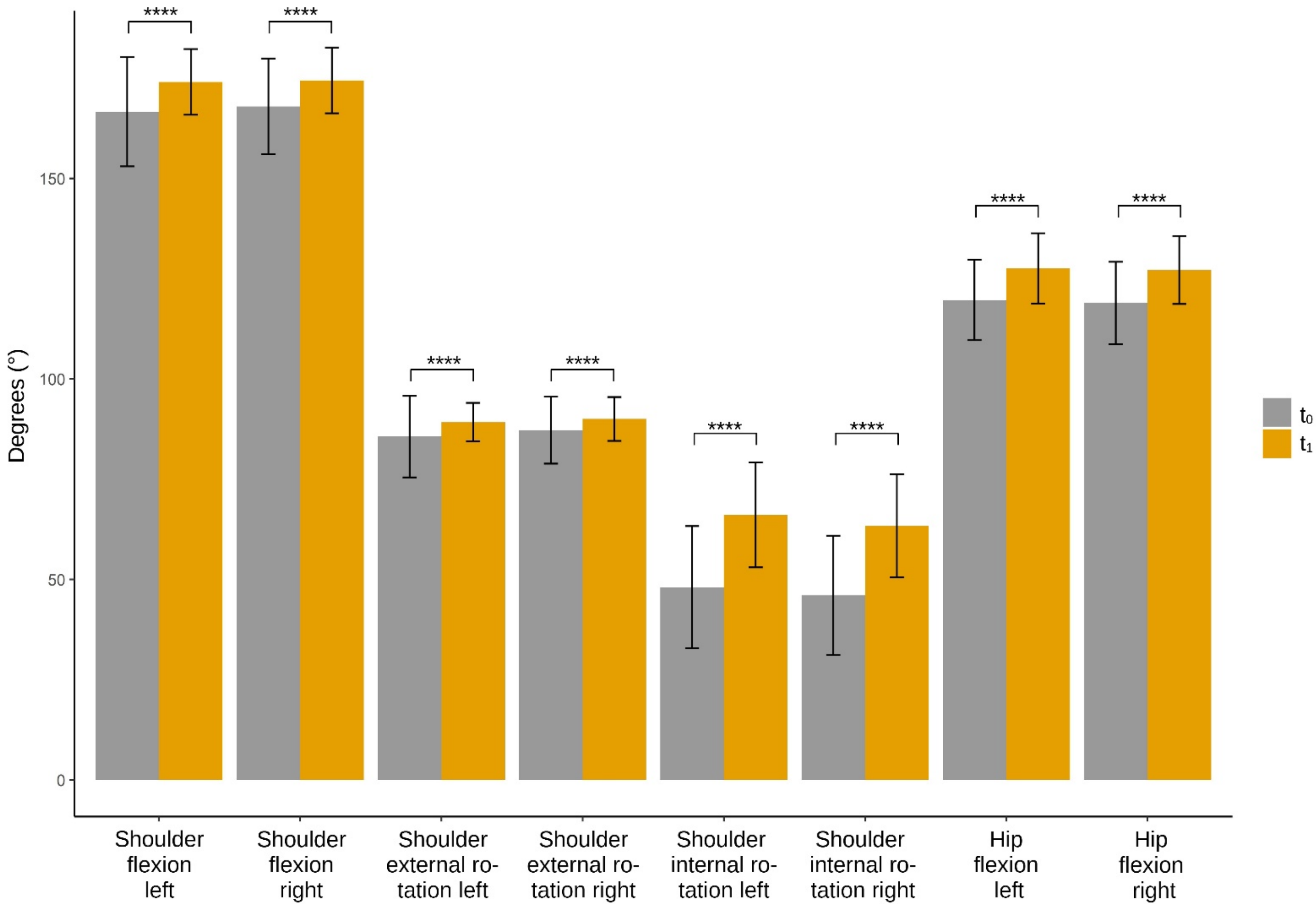

Figure 3. Changes between baseline and after Rolfing Structural Integration treatment. t_0, baseline measurement; t_1, measurement after treatment. Significant at the level **** < 0.0001

It is well known that force can be transmitted via myofascial continuities [6,28]. In a systematic review of cadaveric studies, Krause et al. [28] investigated that the posterior myofascial chain in particular is capable of transmitting significant forces from the plantar aponeurosis via the gastrocnemius, the harmstring muscles to the TLF and the erector spinae muscle. Wilke et al. [6] also confirmed these findings in vivo. It can be assumed that SI treatment had an effect on these myofascial force transmission systems. Therefore, the restoration of inadequate gliding properties of muscles, tendons, nerves, and soft tissues could be a specific SI effect [11]. It is likely that sciatic nerve stiffness plays a critical role in hip motion. Mechanical forces acting on peripheral nerves could alter structures far beyond the moving joint [29]. Therefore, it is possible that SI treatments acting on the sciatic nerve could improve hip flexion.

Manual therapy techniques such as Myofascial Release or Osteopathic Manipulative Treatment have an immediate impact on trunk and pelvic shape parameters [30,31]. It is likely that these changes are due to immediate neuromotor muscle changes, so one may ask whether SI has a similar effect that lasts over a longer period of time, as shown by the results of this study [32]. Here, SI treatment may have altered mechanoreceptors in fascial tissue (e.g., in the epi-/peri-/endomysium, fascia profunda, ten-dons, and joint capsules).

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These may have triggered changes in muscle tone, hydration, and neurological effects, which was likely achieved by the interventions in this study [12,33].

There were no significant effects of the interventions on SBN and FFD, but there was a trend for a slight increase in right SBN (+2%, $p = 0.05$) and a decrease in FFD (-25%, $p = 0.08$). ven though there was only a statistical trend, was surprising, as this parameter was also expected to increase by the mechanisms mentioned above. Chen et al. [34] found no changes in FFD after 7 weeks of flexibility training in participants with low flexibility, but their results showed that erector spinae and hamstring activation, pelvic tilt, and lumbosacral angle were significantly altered after training. This is consistent with the results of this study, in which most of the AROM parameters studied increased, with the exception of FFD.

4.3 Age-related treatment effects

In older people it is known that the fasciae lose flexibility and become thicker with age [35]. Hence the hypothesis that SI, as a treatment method that acts on this tissue in particular, has a different effect in older people than in younger people. However, in contrast to James et al. [10], this study does not show age-related treatment effects. No interaction between age and treatment was found in the four-way ANOVA. Groups were divided into younger and older subjects based on mean age of 40 years. In the study by James et al., the mean age was much higher, 52 years. It is possible that the discrimination age of 40 years is not sufficient to create two groups with appreciable enough age-related differences [36]to detect treatment interactions between older and younger subjects. Further studies need to take this into account and therefore choose a different age of discrimination or even form more than two age groups.

4.4 Limitations

The secondary analysis study presented here had the strengths mentioned above, particularly enhanced external validity due to data acquisition of patients in a running practice over a representative period of 23 years, but also the limitations of a retrospective uncontrolled study.

Pain data were not available in the patients' medical records evaluated. James et al. [10][37] included these data and provided results for this in the previous study. There was also no control group to which we could compare the SI-treated subjects and no follow-up data. Therefore, the study can only provide limited information on the clinical relevance of the results. Future studies on SI should consider a control-group design and include follow-up data in their designs. It is furthermore recommended for future work to collect patient-centered information on disability improvements and functional enhancements (e.g., Oswestry Disability Questionnaire, Tinnetti Performance-Oriented Assessment of Mobility, Berg Balance Scale, Fullerton Advanced Balance Scale, Dynamic Gait Index, Balance Efficacy Scale, Pain Disability Index).

The aim of this work was to extend the cervical spine AROM parameters investigated in a previous study for the shoulder and hip. According to Abbott et al. [38], such observations represent an appropriate design for this type of study to quantify AROM changes due to SI treatment. This must be seen in light of the lack of SI studies to date (only 13 results are listed on PubMed with the search string: "("structural integration") AND (rolf OR rolfing)". Although the level of evidence from this observational study is below that of a randomized control trial, the results are particularly useful given the paucity of studies that have examined the efficacy of SI therapy and may also provide valuable baseline information for the development of subsequent comprehensive, high-quality studies.

5. Conclusions

This work suggests that 10 SI sessions, when delivered by a physical therapist with advanced SI certification, increase shoulder and hip mobility. It is likely that SI interventions produce multiple changes in the components of myofascial chains that could help maintain upright posture in humans and reduce inadequate compensatory patterns. SI affects the outcome of the AROM parameters left shoulder flexion and external rotation of both shoulders differently in women and men. Further investigation is needed to determine if similar or more advanced results are also obtained in an experimental setting with a randomized control trial design.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data can be made available by the author upon request.

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Conflicts of Interest: The authors declare no conflict of interest.

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