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Immediate Effects of Bilateral Sacroiliac Joint Manipulation on Plantar Pressure Distribution in Asymptomatic Participants

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Abstract

Objective: To investigate the immediate effects of manipulation of bilateral sacroiliac joints (SIJs) on the plantar pressure distribution in asymptomatic participants in the standing position.
Design: Randomized, controlled, double-blind clinical trial.
Participants: Sixty-two asymptomatic men and women (mean age, 20.66 ± 2.56 years) randomly assigned to 2 groups.
Interventions: The experimental group underwent mobilization without tension of the hips in the supine position and high-velocity, low-amplitude manipulation in the SIJs bilaterally. The control group underwent only mobilization, without tension of the hips in supine position.
Outcome Measures: Pre- and postintervention outcomes measured by an assessor blinded to the treatment allocation of the participants included a baropodometric analysis performed by using a force platform. Baseline between-group differences were examined with a Kolmogorov-Smirnov test. A chi-square test was used for categorical data. Analysis of covariance (ANCOVA) was used to assess differences between groups, with the preintervention value as covariant (95% confidence level).
Results: At baseline, no variables significantly differed between groups. Baropodometric analysis showed statistically significant differences in the location of the maximum pressure point in the experimental group ($p = 0.028$). Pre- and postintervention analysis with ANCOVA showed statistically significant differences between both groups in the left hindfoot load percentage (interaction $p = 0.0259$; ANCOVA $p = 0.0277$), right foot load percentage (ANCOVA $p = 0.0380$), and surface of the right forefoot (interaction $p = 0.0038$). There was also a significant effect in the variables that analyze the entire foot (left foot: surface [interaction $p = 0.0452$], percentage of load [ANCOVA $p = 0.0295$]) and between both groups (right foot: weight [interaction $p = 0.0070$; ANCOVA $p = 0.0296$]).
Conclusions: Sacroiliac joint manipulation applied bilaterally in asymptomatic persons resulted in immediate changes in load distribution on plantar support in the standing position. Study limitations and suggestions for future studies are discussed.

Introduction

The postural control system is a complex sensory interaction mechanism that integrates kinesthetic memory and visual, tactile, proprioceptive, and statoacoustic information.[1–7] After analysis, the central nervous system provides a response or changes the postural attitude, starting the motor control system.[5,8,9] These motor reactions are interventions, often subtle, with three aims: maintain posture, generate anticipatory responses to voluntary movements (feed-forward), or provide an adaptive response to achieve both postural and joint stability.[8–11]

The sacroiliac joints (SIJs) are a key element in maintaining the standing posture. The center of mass,[9] also called the center of gravity,[6] is located in the pelvis. Its stability is essential for the proper transmission of forces to the lower

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limbs and hence the distribution of load between the feet.[6,12,13] It is also the confluence of upward and downward forces, with frequent restrictions.[12–14] Sacroiliac dysfunction is present not only in symptomatic patients[14] but also in asymptomatic people.[15] These joint restrictions may result in both ascending and descending muscular and ligamentous imbalance,[5] as has been shown in the spinal muscles,[16] altering postural stability.[17]

Therefore, sacroiliac dysfunction, like other lower-limb disorders, can alter the standing position and thus affect the transmission of forces and normal plantar pressure distribution;[18] as in people with chronic low back pain, the mechanism in feed-forward activation is impaired.[19] Some authors have reported that the greater pressure during the standing position is normal in the hindfoot.[18,20–22]

Several studies have used computerized baropodometry to assess alterations in lower limbs.[23–26] This instrument has also been used to analyze the different effects of manual therapy techniques on body changes in relation to the support on the ground, both in static[24,25,27,28] and in dynamic[29] settings, with the aim of assessing different variables on postural oscillations, plantar supporting areas, and pressure points. These are objective and reproducible assessment methods.[30]

High-velocity, low-amplitude (HVLA) spinal manipulations affect the proprioceptive system.[11,31–33] Some studies showed proprioceptive changes in the upper extremity after manipulation of the cervical spine.[34–36] This intervention appears to normalize the alterations of the afferent information in the somatosensory system.[35] Haavik et al. (2011) suggest that improved spinal function after a manipulation produces a suitable and accurate integration of afference in the propioception system.[34] Referring to the SIJs, it has been observed that manipulation decreases the H-reflex, evaluated by electromyography and tibial nerve stimulation in the soleus muscle,[37] and decreases muscle tone.[38] Grassi et al. (2011) observed immediate and weekly changes in load standing distribution after a unilateral SIJ manipulation.[24]

The aim of the current study was to investigate the immediate effects of bilateral SIJ manipulation on the plantar pressure distribution in asymptomatic individuals in the standing position.

Materials and Methods

Participants

This randomized, controlled, double-blind clinical trial sought to investigate the immediate changes seen in the standing position after bilateral manipulation of SIJs on plantar support and stability in asymptomatic persons. The study included 62 participants of both sexes, age 18–30 years (mean, 20.66 ± 2.56 years). Exclusion criteria were as follows: (1) abnormalities that alter balance; (2) deformities, orthopedic injuries, or traumatic history in the lower limbs or spine; (3) ventilatory disorders; (4) pain during the study; (5) receipt of physical therapy in the lower limbs or spine in the previous 6 months; (6) participation in vigorous physical activity before the measurements; and (7) contraindication to HVLA manipulation. Participants were randomly assigned to 2 groups: the experimental group ($n = 31$) and the control group ($n = 31$).

Protocol

The participants voluntarily signed informed consent forms for inclusion in the study. They were asked not to perform any physical activity in the 24 hours before the study. Physical analysis was performed to evaluate anthropometric properties (mean body–mass index [BMI], 22.89 ± 3.18 kg/m^2). An initial baropodometric assessment before the intervention was performed by a blinded assessor.

Study participants were placed on a force platform to collect data for the measured variables. After the first measurement the therapist, without knowledge of previous assessments, distributed the participants randomly into two groups. The therapist applied a different intervention in the experimental and control groups. The experimental group received the placebo technique and an HVLA manipulation in the SIJs bilaterally; the control group underwent only the placebo technique. Postintervention measurement on the force platform was performed by the blinded assessor in the same way 5 minutes after the procedure in each group.

Evaluations

A baropodometric analysis was performed by using a diagnostic support force platform (Modular Electronic Baropodometer, Diasu SRL, Italy) with a capture area of 120 × 40 cm, 1600 sensors, and 200 Hz of frequency.

The participants stood barefoot on the force platform, with arms relaxed in extension of the body and feet slightly apart (5–10 cm). Data were measured for 1 minute. Before the evaluation began, participants were instructed to "Be as still as possible, breathe normally, stare at a point (located 5 m in front of [you]), do not tighten the jaw, not talk and hold in that position until I tell you the measurement has finished."

The outcome measures analyzed before and after the intervention were surface and percentage of load on each forefoot and hindfoot and each foot in its entirety and the location of the maximum pressure point on the plantar support.

Reliability study

Before the study began, a reliability study was conducted with 10 asymptomatic participants. A baropodometric analysis was performed as described earlier, and three independent reviewers analyzed the results. The intraclass correlation coefficient showed high interexaminer reliability, with all variables above 0.7 (average intraclass correlation coefficient for all variables, 0.83 [95% confidence interval, 0.58–0.93]).

Intervention

In the experimental group, mobilization of the hips without tension was applied in the supine position and HVLA manipulation was applied in the SIJs bilaterally. Each side was manipulated with the participant lying on the contralateral side to be treated, a complete rachis rotation was adjusted, and hip flexion tension focus was applied in the SIJ. The forearm was placed in contact with the iliac to manipulate along the joint. After this position, HVLA manipulation to open the SIJ was done (Fig. 1).

FIG. 1. Global sacroiliac joint manipulation technique.

In the control group, only the placebo technique (mobilization without tension of the hips in the supine position) was applied.

Statistical analysis

Data were analyzed by using the SPSS software package (version 15.0; SPSS, Inc., Chicago, Illinois). Means and standard deviations were calculated for each variable. A normal distribution of quantitative data was assessed by means of the Kolmogorov-Smirnov test ($p > 0.05$). A chi-square test was used for categorical data. Analysis of covariance (ANCOVA) was used to assess differences between groups, with the preintervention value as covariant, group as the independent variable, and postintervention value as the dependent variable. Because of interactions between the regression lines for each group in some variables, this condition has been contrasted by introducing an interaction term in the model to take into account that the growth of the dependent variable differs in each group. The statistical analysis was conducted at a 95% confidence level. A p-value < 0.05 was considered to indicate statistical significance in all analyses.

Results

The experimental group consisted of 31 participants (21 women and 10 men), with a mean age of 21.210 ± 2.735 years and a BMI of 22.92 ± 3.75 kg/m^2. The control group consisted of 31 participants (22 women and 9 men), with a mean age of 20.11 ± 2.29 years and a BMI of 22.87 ± 2.55 kg/m^2. No significant differences between groups in any variables at baseline were shown by the Kolmogorov-Smirnov test.

Regarding baropodometric data, the location of the maximum pressure point on the plantar support during measurement was significantly different in the experimental group ($p = 0.028$) (Table 1). After the SIJ manipulation, the percentage of participants with maximum pressure point in the forefoot decreased from 25.8% to 9.7%. In the control group, this percentage increased from 16.1% to 25.8%.

Differences in means of variables evaluated between pre- and postintervention are interesting (Table 2), and ANCOVA showed statistically significant differences between both groups for some variables (Table 3). In the hindfoot load percentage there were significant differences; in the left foot, both in the interaction ($p = 0.0259$) and in ANCOVA ($p = 0.0277$) between groups, this value decreased in the experimental group. In the right foot, ANCOVA showed a statistically significant (p = 0.0380) increase in the experimental group. The surface of the right forefoot showed statistically significant differences for the interaction between groups ($p = 0.0038$), decreasing more in the experimental group than in the control group.

After the SIJ manipulation, the variations in surface, percentage of load, and weight of the feet were different in each group. In relation to the variables for the entire foot, first for the left foot, the supporting surface increased in both groups, while the percentage of load and the weight decreased in the experimental group and increased in the control group. The three variables showed significant differences between the groups: the surface variable on the interaction between the groups ($p = 0.0452$), the percentage of load variable on ANCOVA ($p = 0.0295$), and the weight

Table 1. Chi-Square Test (Location of the Maximum Pressure Point on the Plantar Support)

Group	*Value*	p-*Value*
Experimental group		
Chi-square	14,135	0.028*
Participants (*n*)	31	
Control group		
Chi-square	8584	0.477
Participants (*n*)	31	

*Statistically significant difference; $p < 0.05$.

Table 2. Means and Means Differences Pre–PostIntervention for Variables of Each Foot by Groups

Outcome measures	*Mean preintervention*	*Mean postintervention*	*Mean difference pre–post*	*SD*	*SE*	*95% CI*	
						Lower	*Upper*
Experimental group							
LFF: surface (mm²)	45.77	44.03	1.74	5.67	1.02	−0.34	3.82
LFF: load (%)	19.84	19.39	0.45	3.29	0.59	−0.76	1.66
LHF: surface (mm²)	50.68	50.26	0.42	4.36	0.78	−1.18	2.02
LHF: load (%)	28.55	28.32	0.23	4.66	0.84	−1.48	1.94
RFF: surface (mm²)	53.58	50.42	3.16	7.24	1.30	0.51	5.82
RFF: load (%)	24.00	23.16	0.84	4.82	0.87	−0.93	2.61
RHF: surface (mm²)	51.65	51.26	0.39	6.32	1.14	−1.93	2.71
RHF: load (%)	27.61	29.13	−1.52	3.35	0.60	−2.74	−0.29
LF: surface (mm²)	93.87	94.29	−0.42	14.82	2.66	−5.86	5.02
LF: load (%)	48.39	47.71	0.68	5.11	0.92	−1.20	2.55
LF: weight (kg)	30.82	30.12	0.70	3.61	0.65	−0.63	2.03
RF: surface (mm²)	102.61	101.68	0.94	19.40	3.48	−6.18	8.05
RF: load (%)	51.61	52.29	−0.68	5.11	0.92	−2.55	1.20
RF: weight (kg)	32.54	33.24	−0.70	3.61	0.65	−2.03	0.63
Control group							
LFF: surface (mm²)	47.13	46.32	0.81	6.80	1.22	−1.69	3.30
LFF: load (%)	21.06	20.94	0.13	3.80	0.68	−1.27	1.52
LHF: surface (mm²)	50.19	51.48	−1.29	4.38	0.79	−2.90	0.32
LHF: load (%)	27.00	29.48	−2.48	3.89	0.70	−3.91	−1.06
RFF: surface (mm²)	51.48	50.32	1.16	10.05	1.81	−2.53	4.85
RFF: load (%)	22.52	21.29	1.23	4.29	0.77	−0.35	2.80
RHF: surface (mm²)	54.77	54.42	0.35	4.88	0.88	−1.43	2.14
RHF: load (%)	29.55	28.94	0.61	3.19	0.57	−0.56	1.78
LF: surface (mm²)	97.32	97.81	−0.48	9.09	1.63	−3.82	2.85
LF: load (%)	48.06	49.77	−1.71	4.87	0.88	−3.50	0.08
LF: weight (kg)	30.60	31.74	−1.14	3.05	0.55	−2.26	−0.02
RF: surface (mm²)	106.26	104.42	1.84	11.29	2.03	−2.30	5.98
RF: load (%)	51.94	50.23	1.71	4.87	0.88	−0.08	3.50
RF: weight (kg)	33.00	31.87	1.14	3.05	0.55	0.02	2.26

CI, confidence interval; LF, left foot; LHF, left hindfoot; LFF, left forefoot; RF, right foot; RHF, right hindfoot; RFF, right forefoot; SD, standard deviation; SE, standard error.

variable on both the interaction ($p = 0.0466$) and ANCOVA ($p = 0.0142$).

In the right foot, the supporting surface in the control group decreased twice the amount seen in the experimental group. The percentage of load and the weight again behaved differently in both groups, increasing in the experimental group and decreasing in the control group, with significant differences for the weight variable both in the interaction ($p = 0.0070$) and ANCOVA ($p = 0.0296$).

Discussion

The results indicate that the changes in measurements in both groups are different, demonstrating that bilateral manipulation of SIJs produces changes in some baropodometric variables, with statistical significance at $p < 0.05$. This observation reinforces the results of other studies reporting baropodometric variations after the application of HVLA techniques.[24,25] However, a few studies that evaluated baropodometric changes after HVLA techniques showed even fewer changes after SIJ manipulation.

This study was performed in asymptomatic participants, as was done in other studies,[24,27,39] knowing that some of these may have SIJ dysfunction.[15] Asymptomatic participants were enrolled to avoid inclusion of those with an active central sensitization clinical condition.[40]

There is some controversy in the literature regarding the effectiveness of diagnostic tests for palpation and mobility of the SIJs. Some authors have not demonstrated the effectiveness of these tests,[41–44] whereas others report efficacy in some combination of tests.[45] Therefore, without performing a preliminary test in these asymptomatic participants, the current study applied a bilateral SIJ intervention, as was done in other studies,[27,28] because SIJ manipulation affects muscle tone only of the ipsilateral lower limb muscles.[38]

Schiffer (2001) has shown that 60% of the weight support should be on the hindfoot and 40% on the forefoot, with a tolerance of ±4%.[20] Other authors also claim that maximum load should be on the hindfoot.[18,20–22,46] This is consistent with the results obtained in the current study, in which both the experimental group and the control group showed an increase in the hindfoot percentage of load on post-intervention measurement. However, the percentage of participants in the experimental group with the point of maximum pressure in the hindfoot after manipulation was significantly greater, increasing from 74.2% to 90.4%, whereas in the control group this percentage decreased from 83.9% to 74.2%. Gravante and colleagues (2005) obtained results in persons with normal foot architecture, wherein the forefoot and hindfoot had a percentage close to 50% and the percentage of claw feet in the hindfoot decreased to 48.5% among women and 44.9% among men.[23] Other authors have

Table 3. Effectiveness of Bilateral Sacroiliac Joint Manipulation: Intergroup Comparison with Analysis of Covariance

Outcome measures	*DF*	*Statistic*	*SE*	p-*Value*
LFF: surface (mm^2)	58	Interaction	0.08	0.5693
		ANCOVA	0.71	0.3370
RFF: surface (mm^2)	58	Interaction	0.10	0.0038*
		ANCOVA	0.95	0.5743
LFF: load (%)	58	Interaction	0.09	0.6381
		ANCOVA	0.41	0.3360
RFF: load (%)	58	Interaction	0.10	0.7297
		ANCOVA	0.50	0.2662
LHF: surface (mm^2)	58	Interaction	0.05	0.9423
		ANCOVA	0.52	0.1235
RHF: surface (mm^2)	58	Interaction	0.07	0.3613
		ANCOVA	0.68	0.6288
LHF: load (%)	58	Interaction	0.09	0.0259*
		ANCOVA	0.49	0.0277*
RHF: load (%)	58	Interaction	0.12	0.3072
		ANCOVA	0.43	0.0360*
LF: surface (mm^2)	58	Interaction	0.06	0.0452*
		ANCOVA	1.18	0.6099
RF: surface (mm^2)	58	Interaction	0.08	0.4014
		ANCOVA	1.63	0.8285
LF: load (%)	58	Interaction	0.10	0.9336
		ANCOVA	0.49	0.0295*
RF: load (%)	58	Interaction	0.08	0.4014
		ANCOVA	1.63	0.8285
LF: weight (kg)	58	Interaction	0.06	0.0466*
		ANCOVA	0.35	0.0142*
RF: weight (kg)	58	Interaction	0.07	0.0070*
		ANCOVA	0.40	0.0296*

*Statistically significant difference; $p < 0.05$.
ANCOVA, analysis of covariance; DF, degrees of freedom.

shown different results, with a higher percentage of pressure in the forefoot than in the hindfoot, but this study was conducted among patients with an ankle sprain.[25]

Other studies that evaluated the effects of manipulations by using force platforms obtained variations in fluctuations of center of gravity that have affected support surface and load distribution.

In an uncontrolled trial, Grassi et al. (2011) found a significantly different decrease in pressure peak between both feet after sacroiliac dysfunction manipulation. However, differences in the areas of support were not significant.[24]

Another controlled trial by López et al. (2007) showed that after manipulation of the talo-crural joint in patients with ankle sprain, the load percentage in forefoot and hindfoot bilaterally changed significantly. However, unlike in the current study, the forefoot loading percentage increased and the hindfoot loading percentage decreased, with postintervention values of 66.34% in the forefoot and 33.66% in the hindfoot.[25]

Alburquerque and colleagues (2009), in a controlled trial with bilateral manipulation of the talo-crural joints in asymptomatic individuals, noticed a significant decrease in the range of anterior-posterior oscillation, as well as changes in the surface area of displacement of the center of gravity.[27]

In the current study, load distribution significantly differed between forefoot and hindfoot; more pressure was brought to the hindfoot after the intervention, while the lateral distribution, by changing load from left to right between feet, showed decreasing significant differences in the load percentage (ANCOVA, $p = 0.0295$) and in the supporting surface (ANCOVA interaction, $p = 0.0452$) of the left foot. These findings differ from those of Grassi and colleagues (2011),[24] who reported that peak pressure modifications were not accompanied by support surface changes.

The results obtained—that SIJ manipulation in asymptomatic persons modifies the plantar pressure distribution with decreasing weight on the forefoot—suggests that it would be interesting and convenient in future studies to analyze this intervention in individuals in whom an increased forefoot pressure may be a problem, such as people with metatarsal pain[47] or diabetes.[48,49] It would also be interesting to do a follow-up study to prove its lasting effect on postural control.

If manipulation-mobilization did not alter the position between the sacrum and the ilium, as evaluated by roentgen stereophotogrammetric analysis in the standing position,[50] the variation in force transmission on the plantar support can be due to other changes after bilateral manipulation of the SIJs, such as the change in sensory integration (afferent)[11,32,34–36] or in the efficiency of the motor control system (efferent)[32,37,38,51] postural control. Many studies found distance effects in the musculoskeletal system after HVLA spinal manipulations.[34,36–38,51] This is consistent with the significant changes found in the current study in some variables, such as load distribution and support surface after the bilateral SIJ intervention.

The current study does have some limitations. Both intrasubject variability baropodometric data and the sample size used may have influenced the differences found between the groups, thereby explaining the lack of additional statistically significant differences. Furthermore, conducting the study in asymptomatic individuals makes it necessary to develop future studies with participants who have weight distribution postural alterations to the lower limbs.

In conclusion, HVLA manipulation of the SIJs applied bilaterally in asymptomatic participants showed immediate changes in load distribution on the plantar support in the standing position. This redistribution is probably obtained by homogenization between both feet of the support, reducing the support on the forefeet and increasing support on the hindfeet, accompanied by a lateral displacement of the load and weight distribution.

Author Disclosure Statement

No competing financial interests exist.

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