Influence of massage and selective gymnastics on roentgenometric parameters of the spinopelvic sagittal balance in patients with sacroiliac joint dysfunction

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Published online: November 30, 2021

(Accepted for publication November 15, 2021)

DOI:10.7752/jpes.2021.s6442

Abstract:

Spinopelvic sagittal balance (SSB) and standing posture are influenced by pelvic morphology and especially pelvic inclination (PI). Abnormal sagittal spine alignment makes it difficult to maintain proper balance. **Purpose of the research** is to study the effect of massage and special physical exercises on roentgenometric parameters of SSB in patients with sacroiliac joint dysfunction (SJD). **Data and methods.** A prospective roentgenometric study was performed. The study involved 39 patients with sacroiliac joint dysfunction (SJD). The volunteer group consisted of 24 students who regularly go in for sports. The inclusion criteria for patients in the study were: localization of pain in the area of the spinae iliaca posterior superior, radiating to the groin, buttocks or thigh; history of pain for more than 3 months; failure of previous conservative treatment; positive 4 or more of 6 provocative tests. The exclusion criterion was positive only 1–3 of the listed provocative tests. The research materials were approved by the Bioethics Committee of the State institute “Sytenko Institute of Spine and Joint Pathology of National Academy of Medical Sciences of Ukraine” (Protocol No. 201 dated 02.03.2020). All volunteers and patients underwent roentgenography of the lumbar spine with hip joints in the standing position according to the standard technique. Patients underwent roentgenography before and after the course of massage and special physical exercises. **Results.** The pelvic tilt PT parameter in patients was 38° (33°; 40°) versus 11° (4.5°; 15.5°) in the volunteer group. The sacral cranial plate slope SS parameter in patients and volunteers was, respectively, 14° (7°; 19°) and 42° (39°; 46°). At the same time, there were no statistically significant differences in the PI parameter (52° (46°; 62°) – patients, 53.5° (46°; 62°) – volunteers. Despite the change in the roentgenometric parameter of the pelvic inclination PI by an average of 5°, multidirectional relative to the rate of change in SS and PT parameters in patients with SJD in the aggregate ensure the stability of this PI parameter, keeping its values as close to the original as possible. **Conclusions.** Massage and physical exercises are effective treatments for recovery of SSB in patients with SJD. Changes in the anatomical roentgenometric parameter of the inclination of pelvis (PI) are associated, firstly, with degenerative changes in the sacroiliac joint, spine, hip joints, and secondly, with a measurement error.

Key words: physical exercises, massage, sacroiliac joint dysfunction, rehabilitation, inclination of pelvis

Introduction

Spinopelvic sagittal balance (SSB) and standing posture are influenced by pelvic morphology and especially pelvic inclination (PI) (Schwab et al., 2010; Roussouly & Nnadi, 2010). Abnormal sagittal spine alignment makes it difficult to maintain proper balance (Offierski & MacNab, 1983).

Sacral cranial plate slope (SS) and pelvic tilt (PT) are commonly used pelvic parameters that are considered positional due to their dependence on body position on roentgenometric examination (Fig. 1). In this case, the pelvic inclination (PI) is considered an anatomical parameter, since it does not change when the position of the body transposes (Schwab et al., 2010; Roussouly & Nnadi, 2010).

The PI parameter regulates the spinopelvic sagittal balance and determines the optimal lumbar lordosis, which also indicates its importance (Legaye et al., 1998). Many researchers talk about a strong correlation between PI, SS and PT, which is expressed in the formula: $PI = SS + PT$ (Labelle et al., 2004; Lafage et al., 2008; Roussouly et al., 2005; Vaz et al., 2002).

Pelvic inclination (PI) remains the most studied parameter of spinopelvic balance (Vrtovec et al., 2012). This parameter was proposed by Duval-Beaupère et al in 1992 (Duval-Beaupère et al., 1992).

At the same time, a number of authors believe that the sacrum forms a rigid pelvic ring and does not move relative to the pelvic bones. It moves relative to the bicoxofemoral axis only as part of the pelvis as a single node (Philippot et al., 2009; Stureson et al., 2000; Jackson et al., 1998).

There is a change in the sacrum mobility relative to the pelvic bones in patients with sacroiliac joint dysfunction (SJD) (Kumar & Lenert, 2017; Vleeming et al., 2012). This can affect the increase in pelvic inclination (PI).

Pelvic inclination (PI) is measured between a line drawn perpendicular to the sacral cranial plate from the middle of the cranial plate S1 (4) and a line connecting the middle of the cranial sacral plate to the bicoxofemoral axis point (5) (Fig. I) (Shah et al., 2019).

Figure I. 1 – point denoting the middle of the cranial plate of the sacrum; 2 – point denoting the projection of the bicoxofemoral axis; 3 – a line drawn along the cranial plate of the sacrum; 4 – a line drawn perpendicular to the cranial plate of the sacrum from point 1; 5 – line connecting the middle of the cranial plate of the sacrum and the point of projection of the bicoxofemoral axis; 6 – horizontal line; 7 – vertical line; 8 – projection point of the horizontal mobility of the sacrum at the level of S2 vertebra

A number of authors believe that the normal PI value is on average $57^{\circ} \pm 10^{\circ}$ (Peleg et al., 2007a; 2007b; Mac-Thiong et al., 2010; Lazennec et al., 2000). At the same time, a larger PI indicates a more inclined pelvis (Peleg et al., 2007a; 2007b; Mac-Thiong et al., 2010; Lazennec et al., 2000). At the same time, the optimal SSB is poorly defined (Lafage et al., 2008; Jentzsch et al., 2013).

The problem raised concerns the rehabilitation of professional sports activities related to the safety of sports (Popovych et al., 2020a), the resilience of athletes (Popovych et al., 2021a), mental states (Popovych & Blynova, 2019; Popovych et al., 2021d; 2021e), the physical and mental stress of athletes who are on the verge of human capabilities (Popovych et al., 2020b; 2021b; 2021c).

Purpose is to study the effect of massage and special physical exercises on the roentgenometric parameters of SSB in patients with sacroiliac joint dysfunction (SJD).

Material and methods

A prospective roentgenometric study was performed. The study involved 39 patients with sacroiliac joint dysfunction (SJD), 20 women and 19 men, aged 16 to 61. The average age of the patients was 37 years.

The volunteer group consisted of 24 students who regularly go in for sports, 14 women and 10 men aged 18 to 34. The average age of the participants was 23.29 years.

The inclusion criteria for patients in the study were:

- 1) localization of pain in the area of the spinae iliaca posterior superior, radiating to the groin, buttocks or thigh;
- 2) history of pain for more than 3 months;
- 3) failure of previous conservative treatment;
- 4) positive 4 or more of 6 provocative tests: a) Stork test, b) ASLR test from 1 to 4 points, c) Fortin test, d) test for blocking the sacroiliac joint from a lying position - sitting, e) Gaenslen test, f) push test.

The exclusion criterion was positive only 1 – 3 of the listed provocative tests (Laslett et al., 2003; Vleeming et al., 2008).

The research materials were approved by the Bioethics Committee of the State institute “Sytenko Institute of Spine and Joint Pathology of National Academy of Medical Sciences of Ukraine” (Protocol No. 201 dated 02.03.2020).

All volunteers and patients underwent roentgenography of the lumbar spine with hip joints in the standing position according to the standard technique. Patients underwent roentgenography before and after the course of massage and special physical exercises. The following parameters were measured on the obtained roentgenograms in the sagittal plane (Fig. II):

Figure II. 1 – the angle of sacral cranial plate slope (SS); 2 – the angle of pelvic tilt (PT); 3 – the angle of pelvic inclination (PI). If the contours of the hip joints on the roentgenograms did not match, then the center of each hip joint was found and connected with a line. The middle of this line was the projection point of the bicoxofemoral axis; 4 – distance from the vertical axis of the L3 vertebra to the projection point of the bicoxofemoral line.

According to a number of authors, with a balanced SSB, a vertical line drawn from the middle of the L3 vertebral body should pass behind the projection of the center of the femoral bones. This arrangement determines the minimum energy consumption of the postural muscles necessary to maintain an upright body position. By changing the distance from the vertical axis L3 to the projection of the bicoxofemoral line, we can talk about a modification in the balance of the lumbar-pelvic region, as an integral component of SSB (Irvin, 2018). This distance is also influenced by sacral cranial plate slope SS, the pelvic tilt PT, and the rotation of the pelvis.

All patients with sacral cranial plate slope in the frontal plane in the standing position was more than 1° , which corresponded to a slope of more than 2 mm, underwent correction using a thrust bearing fitted according to the Irwin R.W. method (Irvin, 1991).

The massage was carried out according to the method developed at the State institute “Sytenko Institute of Spine and Joint Pathology of National Academy of Medical Sciences of Ukraine”. The main effect of the massage was directed to the projection area of muscles and ligaments of the sacroiliac joint SJ stabilizers and the vertical position of the body, as well as to the area of their attachment to the bone (Fig. III). For this purpose, the location of the crests of the pelvic bones (crista iliaca) (2) and the lower edge of the costal arch (1) was determined in each patient before the massage. After that, the location projection of the sacrum was determined. This was used to determine spina iliaca posterior superior (3), then crista sacralis lateralis (5). Through the crista sacralis lateralis, a line is drawn to the coccyx. A straight line (4), drawn from the lower edge of the spina iliaca posterior superior to the spina iliaca anterior superior, is the projection of the m. gluteus medius attachment. We find the projection area of the trochanter major os femoris. This is the projection of the attachment points m. gluteus medius and tensor fascia latae.

Figure III. Projection area of muscles and sacroiliac joint's ligaments of stabilizers and vertical position of the body: 1 – the lower edge of the costal arch projection; 2 – crista iliaca projection; 3 – spina iliaca posterior superior projection; 4 – the attachment point m. gluteus medius projection; 5 – crista sacralis lateralis projection; 6 – trochanter major os femoris projection.

The technique of therapeutic physical training consisted of two blocks.

The first block of physiotherapy exercises was aimed at restoring symmetrical coordinated contraction of the muscle stabilizers of sacroiliac joint and vertical body position.

The second block of therapeutic exercises was aimed at restoring the strength and endurance of the muscle stabilizers of sacroiliac joint and the vertical position of the body. These muscles include m. piriformis, m. gluteus maximus, m. gluteus medius, m. tensor fasciae latae, m. erector spinae, m. biceps femoris, m. iliopsoas, m. transversus abdominis, m. obliquus abdominis externus, internus, m. rectus femoris, m. quadratus lumborum (Hungerford & Gillear, 2007; Monticone et al., 2004; Vleeming & Stoeckart, 2007). The patients did gymnastics once a day for two weeks.

The data were processed statistically in the software environment Statistica Basic Academic 13 for Windows En (License Number: 139-956-866). Quantitative indicators were presented using the median values (Me) of the lower (LQ) and upper (UQ) quartiles as Me (LQ; UQ). The statistical significance of differences for unrelated samples was checked using the Mann-Whitney U test, for related samples – the Wilcoxon rank-sum test. Correlation dependences were estimated using Spearman's rank correlation coefficient.

Results

The results of measuring the roentgenometric parameters that determine the SSB in patients with SJD before and after the course of massage and physical exercises are given in Tabl. 1.

Table 1. Results of measuring the roentgenometric parameters that determine SSB in patients with SJD before and after treatment.

PI°		SS°		PT°		Distance from the vertical axis L3 to the bicoxofemoral line (mm.)	
Before	After	Before	After	Before	After	Before	After
55	53	33	27	22	26	20	37
71	60	52	47	19	13	8	17
69	67	54	52	15	15	1	7
35	44	29	35	5	9	3	23
46	52	39	39	7	13	8	18
52	45	33	21	19	24	27	32
70	55	37	37	33	18	16	15
48	45	38	40	10	5	12	4
54	57	38	42	16	15	14	18
47	36	40	30	7	6	12	7
81	78	43	46	38	32	12	18
63	62	48	49	15	13	13	6
30	27	24	19	6	8	21	24
46	51	38	37	8	14	14	17
54	50	38	37	16	12	23	13
47	45	35	35	12	10	16	17
62	62	30	30	32	32	23	36
43	43	40	40	4	3	-4	-5
46	41	39	30	7	11	17	30
63	59	40	40	23	19	18	15
75	82	53	57	22	25	15	15
47	52	34	37	13	14	13	7
53	46	39	32	14	14	3	7
61	56	43	40	18	16	5	4
40	42	30	30	10	12	13	16
30	26	24	24	6	2	13	2
57	60	38	38	19	22	10	10
46	38	39	33	7	5	13	6
46	41	34	25	12	16	12	13
49	40	34	38	15	2	8	-4
71	79	44	54	27	25	14	9
62	47	38	26	24	21	15	17
41	42	32	37	9	5	7	4
60	60	60	48	0	12	-10	1
33	28	32	24	1	4	12	3
52	46	30	24	22	22	18	21
41	36	32	28	9	8	40	30
81	90	67	67	14	23	-9	-8
37	40	34	30	3	10	11	15

When analyzing the results obtained, attention is drawn to the fact that the anatomical parameter PI after treatment changed, on average, by 5°. Comparison of groups of patients before treatment and volunteers revealed the presence of statistically significant differences in the PT parameter (the Mann–Whitney U test, $p < .01$) and SS parameter (the Mann–Whitney U test, $p < .01$), Fig. IV.

Figure IV. Box plots of PT parameter (left) and SS parameter (right) in patients (gr. 1) before treatment and volunteers (gr. 0).

The PT parameter in patients was 38° (33°; 40°) versus 11° (4.5°; 15.5°) in the volunteer group. The SS parameter in patients and volunteers was, respectively, 14° (7°; 19°) and 42° (39°; 46°).

At the same time, there were no statistically significant differences in the PI parameter (52° (46°; 62°) – patients, 53.5° (46°; 62°) – volunteers and the distance from the vertical axis L3 to the bicoxofemoral line (15 mm. (6 mm; 18 mm) – patients, 9.5 mm (2.5 mm; 16 mm) – volunteers (Fig. V).

Figure V. Box plots of the PI parameter (left) and the distance from the vertical axis L3 to the bicoxofemoral line (right) in patients (gr. 1) before treatment and volunteers (gr. 0).

Thus, despite the change in the roentgenometric parameter of the pelvic inclination PI by an average of 5°, multidirectional relative to the rate of change in SS and PT parameters in patients with SJD in the aggregate ensure the stability of this PI parameter, keeping its values as close to the original as possible.

As a result of the treatment, statistically significant changes were recorded only in relation to the PT parameter (the Wilcoxon rank-sum test, $p = .023$) (Fig. VI).

Figure VI. Box plots of the PT parameter dynamics as a result of the treatment

The median values before and after treatment were 38° and 37° with an interquartile range (33°; 40°) and (39°; 40°). However, it should be noted that after the treatment, statistically significant differences in the PT parameter in patients from the corresponding values of the volunteer parameter (the Mann–Whitney U test, $p < 0.01$) remained.

At the same time, insignificant changes in the values of the PT parameter made it possible to arrest the pain syndrome and restore the balance of muscle stabilizers of sacroiliac joint and vertical body position. However, they did not bring the pelvic inclination PI parameter beyond the range of group variability. Despite the visual changes (52° (46°; 62°) before treatment, 47° (41°; 60°) – after treatment, there were no statistically significant differences (Fig. VII).

Figure VII. Box plots of the PI parameter dynamics as a result of the treatment

The research of correlations between the studied parameters in the group of volunteers, patients before conservative treatment and patients after treatment (Tabl. 2) is of a fairly similar nature, with the exception of the interconnection between SS indicators and the distance from the vertical L3 axis to the bicoxofemoral line.

Table 2. Correlations between the studied parameters in the group of volunteers, patients before conservative treatment and patients after treatment

Correlated parameters	N	R	p
Volunteers			
PI & PT	24	0,79	0,00
PI & SS	24	0,68	0,00
PI & Axis L3 to bicoxofemoral line	24	0,30	0,15
PT & SS	24	0,15	0,47
PT & Axis L3 to bicoxofemoral line	24	0,57	0,00
SS & Axis L3 to bicoxofemoral line	24	-0,25	0,24
Patients before treatment			
PI & PT	39	0,68	0,00
PI & SS	39	0,80	0,00
PI & Axis L3 to bicoxofemoral line	39	-0,01	0,96
PT & SS	39	0,19	0,24
PT & Axis L3 to bicoxofemoral line	39	-0,41	0,01
SS & Axis L3 to bicoxofemoral line	39	0,38	0,02
Patients after treatment			
PI1 & PT1	39	0,75	0,00
PI1 & SS1	39	0,77	0,00
PI1 & Axis L3 to bicoxofemoral line	39	0,03	0,86
PT1 & SS1	39	0,21	0,19
PT1 & Axis L3 to bicoxofemoral line	39	-0,40	0,01
SS1 & Axis L3 to bicoxofemoral line	39	0,41	0,01

Note: statistically significant correlations are highlighted in grey

As can be seen from Table 2, if volunteers have no connection between the distance from the vertical axis L3 to the bicoxofemoral line and the sacral cranial plate slope to the horizontal line, then there is a tangible negative ($R = -0.41$ and $R = -0.40$, respectively) statistically significant interrelation in patients before and after treatment.

Discussion

Before treatment, patients with SJD had a large pelvic tilt PT and, correspondingly, a slight sacral cranial plate slope SS. This was accompanied by an imbalance in the muscle stabilizers of sacroiliac joint, vertical body position and pain (Staude, 2018a; 2018b).

On the other hand, the volunteers had a small angle of the pelvic tilt PT and a large angle of sacral cranial plate slope SS.

The foregoing suggests that in order to reduce pain and stabilize the vertical position of the body in patients with SJD the pelvis rotates with an increase in the PT angle. And it is likely that a functional block of the sacrum occurs in the extreme position relative to the pelvic bones, accompanied by a decrease in the angle of sacral cranial plate slope SS.

As a result of the treatment, aimed at restoring the balance of muscle stabilizers of sacroiliac joint and the vertical position of the body and removing the functional block of sacroiliac joint, a statistically significant change in the angle of pelvic tilt PT was observed.

The presence in patients with SJD of a statistically significant interrelation between changes in the angle of pelvic tilt PT, the angle of sacral cranial plate slope SS, and the distance from the vertical axis L3 to the bicoxofemoral line, firstly indicates that the angle of pelvic tilt PT and the sacral cranial plate slope SS directly affect the vertical position of the body and spinopelvic sagittal balance SSB.

Secondly, the balance of muscle stabilizers of sacroiliac joint and vertical body position affects the angle of pelvic tilt PT and the sacral cranial plate slope SS, and, accordingly, the spinopelvic sagittal balance SSB in such patients. The absence of a statistically significant interconnection between the angle of the sacral cranial plate slope SS in volunteers suggests, probably, that in volunteers sacroiliac joint SJ functions as a single mechanism. That is, the sacrum under vertical loading rotates anteriorly relative to the pelvic bones and the pelvic bones posteriorly, compensating for the rotation of the sacrum (that is, a change in the angle of the sacral cranial plate slope SS).

According to some authors, in healthy people, such a roentgenometric parameter as PI increases during childhood and becomes constant in adolescents and adults (Hammerberg et al., 2003; Vaz et al., 2002).

In our patients, PI changes by an average of 5° . This is comparable to the measurement error, which some authors call in the range from 3° to 6° . Some researchers associate this fact with degenerative changes in the hip joints, which may be accompanied by a change in the configuration of the femoral head, its subluxation and dislocation (Boulay et al., 2005; Imai et al., 2019; Lazennec et al., 2000), as well as with the pelvic bones rotation (Bao et al., 2017). Legaye et al in 2014 in his study demonstrated a strong correlation of PI value in people over 60 years old (Legaye & Jean, 2014). He proposed a mechanical theory that PI increases in older patients and affects their SSB. Moreover, the Legaye's study is supported by the Lee et al study, who observed an increase in PI after surgical treatment of spinal deformities in adult patients (Lee et al., 2015). J. Legaye and L. Jean (2014) suggested that sacroiliac joint degenerative changes, as part of spine degenerative changes, may lead to an increase in PI with age. J. W. Moon et al. (2017) in his work proved that PI increases with the transition from a standing position to a lying position by an average of 3.2° . These data overlaps with the data of T. Eddine et al. (2001), who also speaks of an increase in PI by 3.2° with a change in body position.

According to Vrtovec et al. (2013), the interval between the sacrum and the femoral head increases with age. This causes a change in the morphology of the pelvis and an increase in PI. T. Jentzsch et al. (2013) also reports an increase in PI with age.

In addition, the indicated PI change is comparable to the volume of rotational mobility of the sacrum relative to the pelvic bones. According to Stureson, this is $4^\circ - 5^\circ$ (Stureson et al., 2000). In a study on cadavers, Smidt et al speaks of sacroiliac joint mobility in the range from $3^\circ - 17^\circ$ degrees in the sagittal plane, from 7° to the left and 8° to the right (Smidt et al., 1997).

Frymoyer et al speaks of long – term SJ compensatory hypermobility after spinal fusion of the lower lumbar spinal motion segments associated with degenerative changes in the sacrum (Frymoyer et al., 1978). This is confirmed by K.-Y. Ha et al. (2008).

Stureson et al suggests that the SJ is most vulnerable to shear forces (Stureson et al., 2000). When the SJ adjusts to increasing shear forces, sacrum displacement can alter the anatomical interaction between the sacrum and pelvic wings, resulting in an increase in PI and changes in the morphological parameters of the pelvis.

It is likely that degenerative changes in the sacroiliac joint elements in patients with SJ dysfunction are accompanied by a functional block of the sacrum relative to the pelvic bones in the extreme position. This will affect the measurement results, and after treatment, with the restoration of the balance of muscle stabilizers of sacroiliac joint and vertical body position and the elimination of the functional block of the sacrum relative to the pelvis, the normal volume of rotational mobility of the sacrum relative to the pelvis is restored. This also affects the measurement results.

Conclusions

Massage and physical exercises are effective means of restoring spinopelvic sagittal balance SSB in patients with sacroiliac joint dysfunction SJD.

Massage and physical exercises effectively restore the balance of muscle stabilizers of sacroiliac joint and vertical body position in patients with SJD. This allows one to change the positional roentgenometric parameters of the pelvic tilt PT and the sacral cranial plate slope SS.

Our data showed that as a result of rehabilitation treatment, the positional roentgenometric parameters of the pelvic tilt PT and the sacral cranial plate slope SS change in such a way as to keep the anatomical roentgenometric parameter of the pelvic inclination PI unchanged as much as possible.

Changes in the anatomical roentgenometric parameter of the pelvic inclination PI are associated, firstly, with SJ degenerative changes, spine, hip joints, and secondly, with a measurement error.

Conflict of Interest. The authors declare that there is no conflict of interest.

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