



Does Pelvic Asymmetry always Mean Pathology? Analysis of Mechanical Factors Leading to the Asymmetry

by

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Pelvic asymmetry is a phenomenon of dual character. Some describe it in terms of pathology, whereas others report that pelvic asymmetry also occurs in healthy subjects.

A group of 321 subjects showing symmetrical alignment of the pelvis were involved in the study. Different forms of mechanical loads (jumps, resistance exercises of selected muscle groups) were tested for their ability to alter the configuration of the lower girdle. A hand inclinometer was used to measure pelvic asymmetry in standing.

Asymmetrical configuration of the pelvis appears frequently as a consequence of mechanical loading of the lower girdle. It was registered in 25.08% of our study group. The greatest capacity to introduce pelvic asymmetry appeared in cases of asymmetrical loads that were applied in a form of so-called 'mechanical shock' (i.e., a force with great impulse). From this viewpoint, pelvic asymmetry should be regarded as a physiologic adaptative alteration of the locomotory system to transmission of asymmetrical mechanical loads.

Key words: pelvic asymmetry, functional asymmetry, lumbo-pelvo-hip complex

Introduction

Pelvic asymmetry (PA) is a common phenomenon which is often described in connection with various pathological processes affecting the locomotory system, starting from lateral spinal curvatures (Saulicz et al., 1999, 2002; Saulicz, 2000; Stirling et al., 1996), through leg length discrepancies of different aetiologies (Anderson, 1991; Beaudoin et al., 1999; Manello, 1992; Manganiello, 2000; Wagner, 1990) and ending with sacroiliac dysfunction (Cibulka, 1992; Cibulka et al., 1986, 1988; Coventry & Tapper, 1972; DonTigny, 1979, 1985; Erhard &

Bowling, 1977; Fraser, 1978; Golightly, 1982; McGregor & Cassidy, 1983), as well as hip joint dysfunctions (Cibulka et al., 1998), or low back pain (Al-Eisa et al., 2004, 2006; Cibulka et al., 1986; Bernard & Kirkaldy-Willis, 1987; Cassidy, 1992; Dejung & Ernst-Sandel, 1995; Fröhlich & Fröhlich, 1995; Greenman, 1997; Mierau, 1984).

Besides these numerous studies demonstrating opinions that PA is associated with pathology, it can also be observed in healthy subjects with no evidence of any dysfunction (Al-Eisa et al., 2004; 2006). Our previous studies demonstrated that PA was present in 67.3% of a healthy group (aged 18 to 39

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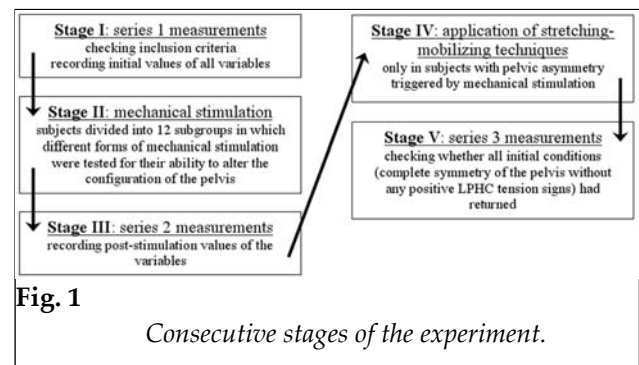
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years) with no pelvic or low back pain (Saulicz et al., 2001). Such a situation gives rise to questions and assumptions that need explanation. Since PA is observed in such a large percentage of healthy subjects, it is probably more appropriate to perceive it as a physiologic phenomenon which is associated with, for example, absorption of routine mechanical loads exerted on the lumbo-pelvo-hip complex (LPHC). Previous reports provide data on the influence of jumps and asymmetrical resistance exercises of selected muscle groups on the alignment of the pelvis (Gnat et al., 2004ab). This article explores a broader range of the mechanical loads applied to the lower girdle.

Material and methods

Material

A total of 321 subjects were involved in the study. Subjects were aged 19 to 37 (mean 22.71 ± 2.76 years; 154 men, 167 women) and all were students of the University School of Physical Education, Katowice, Poland. At baseline, they must have shown symmetrical alignment of the pelvis in the frontal plane, based on outcomes of the palpation examination of anatomical landmarks (anterior and posterior superior iliac spines, the highest points of iliac alae). The acceptable difference in anterior tilt of the right and left innominates was a maximum 1° (measurement described below). With such a difference, taking into consideration some measurement error, we regarded



the subject showing symmetrical alignment of the pelvis. Since both PA and outcomes of some popular tests of 'sacroiliac joint mobility' (standing and sitting flexion tests, Derbolovsky, Piedellu, Lee-Walsh and Gillet sign) show certain association with asymmetric distribution of muscle tension around LPHC (Saulicz, 2001), no subjects with positive outcomes found in any of these six tests were included. Moreover, absence of any pain during the experiment, and absence of any previous injuries and symptomatic dysfunctions in the pelvic and lumbar region of the body (injuries requiring surgical intervention and hospitalization, pain ailments lasting more than two weeks irrespective of their origin) were required. Initially, 912 subjects were recruited and after checking for the inclusion criteria 591 were excluded. The study was approved by the Institutional Bioethical Research Committee and all procedures conformed to the Declaration of Helsinki of 1983. All subjects were informed about the aims of the study and the experimental procedures, and all gave written informed consent.

Table 1

Demographic data on the 12 groups, together with the p-level of homogeneity testing

Group	N	M	F	Mass [kg]	Height [cm]	Age [years]
J.1	29	13	16	63.52 (45-86)	171.50 (154-191)	21.86 (19-27)
J.2	26	12	14	63.22(48-84)	171.87(161-191)	22.87(19-35)
O.A	29	14	15	63.33(47-88)	171.07(157-187)	22.34(19-29)
R.A	28	13	15	63.47(46-84)	171.67(159-186)	22.25(19-29)
P.1	26	13	13	64.87(50-92)	173.33(161-183)	23.30(19-37)
P.2	27	13	14	65.00(42-89)	173.15(154-185)	22.78(19-31)
I.1	26	13	13	64.90(50-94)	173.46(159-185)	22.46(19-29)
I.2	26	12	14	64.61(45-92)	172.50(154-183)	23.35(20-37)
B.1	26	13	13	65.35(51-84)	173.11(158-191)	23.11(19-29)
B.2	26	13	13	64.04(45-89)	172.58(155-183)	22.77(19-31)
R.1	25	13	12	64.32(45-84)	172.20(159-186)	22.56(19-29)
R.2	27	12	15	63.04(46-86)	172.41(155-183)	23.07(19-37)
p-level	---	> 0.05**		> 0.05*	> 0.05*	> 0.05*

J.1 and J.2 – jump down with landing on 1 and 2 feet, respectively; O.A – m. obliquus abdominis; R.A – m. rectus abdominis; P.1 and P.2 – m. piriformis, 1 and 2 sides of the body, respectively; I.1 and I.2 – m. iliopsoas, 1 and 2 sides of the body, respectively; B.1 and B.2 – m. biceps femoris, 1 and 2 sides of the body, respectively; R.1 and R.2 – m. rectus femoris, 1 and 2 sides of the body, respectively; N – number of subjects; M – number of men; F – number of women

Protocol

Consecutive stages of the experiment are depicted in Figure 1. After completion of the first series of measurements (series 1), all persons fulfilling the above-mentioned inclusion criteria were randomly divided into 12 subgroups, in which different forms of mechanical loading were tested for their ability to alter the configuration of the pelvis. Taking into consideration even small effect size (10%), together with 11 degrees of freedom (degrees of freedom for interaction of ANOVA factors), we needed a sample of about 170 subjects to achieve power of ANOVA of 0.9. However, having the opportunity to investigate a larger number of subjects, we continued preparation of the randomization list until the minimal number of subjects in each individual group reached the level of 25. Demographic data on the groups are presented in Table 1. This was followed by the second series of measurements (series 2). The two manual stretching-mobilizing techniques directed to the sacroiliac joints and surrounding soft tissues were then applied to all subjects where PA had been introduced. The ensuing third series of measurements (series 3) were performed with the aim to check whether all initial conditions (i.e., complete symmetry of the pelvis without any positive LPHC tension signs) had returned. This report deals with series 1 and 2 measurements only (the subsequent report will address series 3 measurements).

Intervention

Two general types of loading were distinguished. Type one loads included jump down with landing on one foot, and jump down with landing on two feet. Both of these jumps had the ability to produce a kind of 'mechanical shock' (a term proposed by the authors). This way of loading was named 'external forces loading type' (ground-foot reaction forces). Type two loads included resistance exercises directed to the muscles that locate both attachments within the LPHC (*piriformis* and *ilopsoas* muscles), or directed at locating only one attachment which affects distant kinematic links of the locomotory system (*rectus* and *biceps femoris* muscles, *obliquus* and *rectus abdominis* muscles). This type of loading was named 'internal forces loading type'. Both the external and internal forces loadings were applied in symmetrical and asymmetrical fashion. The following loads were used for the 12 different groups:

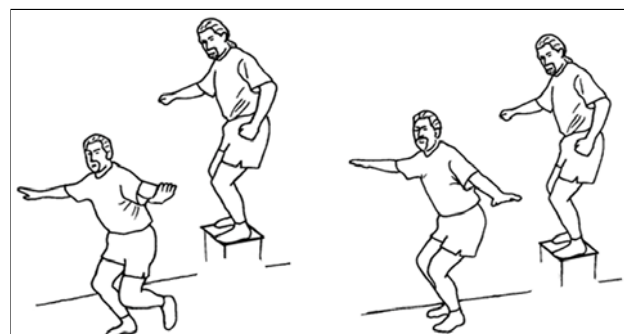


Fig. 2
The 60-cm jump down with landing on one foot (left) and two feet (right)



Fig. 3
Resistance exercises of right obliquus externus (left) and rectus abdominis (right) muscles

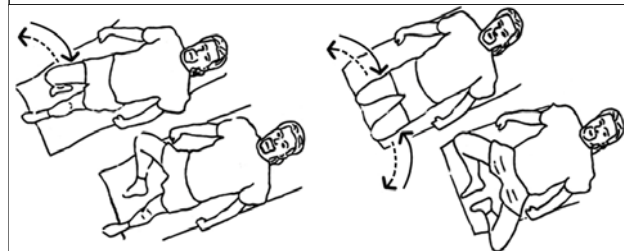


Fig. 4
Resistance exercises of right (left) and right & left piriformis (right) muscles. Dotted arrow indicates direction of the movement, solid arrow indicates direction of the resistance applied

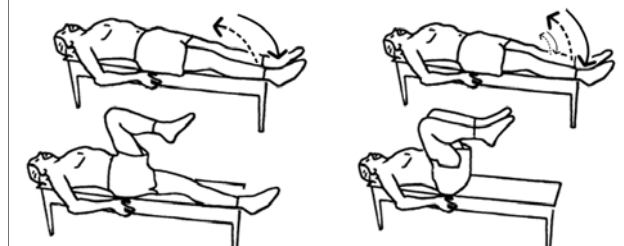


Fig. 5
Resistance exercises of right (left) and right & left iliopsoas (right) muscles

- 60-cm jump down with landing on one foot (J.1 group [jump down with landing on 1 foot]) (Figure 2);
- 60-cm jump down with landing on two feet (J.2) (Figure 2);

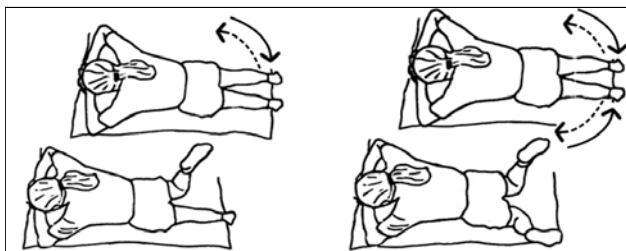


Fig. 6
Resistance exercises of right (left) and right & left biceps femoris (right) muscles

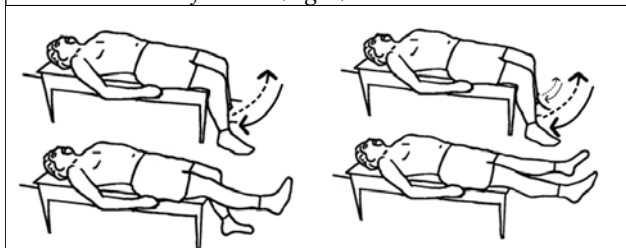


Fig. 7
Resistance exercises of right (left) and right & left rectus femoris (right) muscles

- resistance exercise for the right *obliquus abdominis externus* muscle (O.A [*m. obliquus abdominis externus*]); modified methodology of DeLorme and Watkins using 3 sets of 10 repetitions with a 1 to 1.5-minute break and sub-maximal resistance in a form of upper body weight [abdominal muscles] or applied manually [remaining muscle groups] (DeLorme & Watkins, 1948; Fish et al., 2003); the same approach was used with all resistance exercises) (Figure 3);
- resistance exercise for the *rectus abdominis* muscle (R.A [*m. rectus abdominis*]) (Figure 3);
- resistance exercise for the right *piriformis* muscle (P.1 [*m. piriformis*, 1 lower limb]) (Figure 4);
- resistance exercise of the right & left *piriformis* muscles (P.2) (Figure 4);
- resistance exercise of the right *iliopsoas* muscle (I.1 [*m. iliopsoas*, 1 lower limb]) (Figure 5);
- resistance exercise of the right & left *iliopsoas* muscles (I.2) (Figure 5);
- resistance exercise of the right *biceps femoris* muscle (B.1 [*m. biceps femoris*, 1 lower limb]) (Figure 6);
- resistance exercise of the right & left *biceps femoris* muscles (B.2) (Figure 6);
- resistance exercise of the right *rectus femoris* muscle (R.1 [*m. rectus femoris*, 1 lower limb]) (Figure 7);
- resistance exercise of the right & left *rectus femoris* muscles (R.2) (Figure 7).

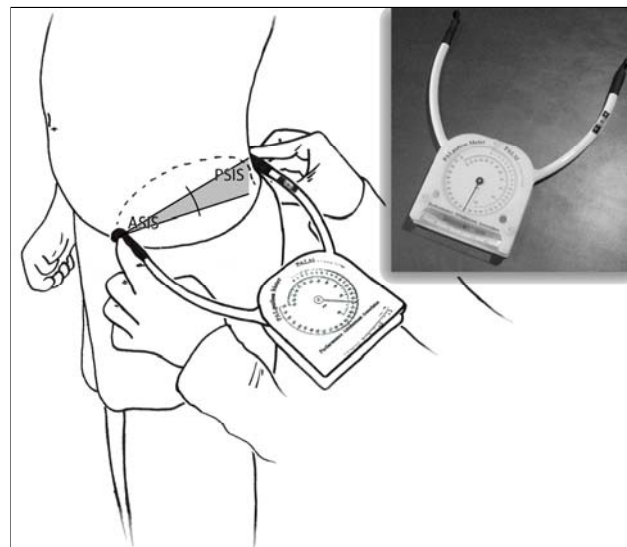


Fig. 8
Mean values and 95% confidence intervals of the magnitude of Pelvic Asymmetry in consecutive series of measurements in individual groups. The outcome of F test and its p-level are also presented.

All mechanical loads reported here are common forms of physical activity, and therefore, do not require additional description. However, it must be pointed out that all resistance exercises (although performed in isolating positions) did not engage only the single muscles used as group identifiers here, but involved whole muscle groups. The individual group name serves to indicate which muscle from the particular muscle group was of most interest to the authors.

Measurements for pelvic configuration

Evaluation of the configuration of the pelvis consisted of measurement of the angle of inclination of the line joining the anterior and posterior superior iliac spines on the right and left side of the body and the horizontal line (Figure 8). The inter-side difference was taken into further consideration. A hand inclinometer (Palpation Meter US Patent 5 327 907, Performance Attainment Associates, St. Paul, USA) (Figure 8) with a precision of $\pm 1^\circ$ was used. During measurements we followed remarks given by Crowell et al. (1994) who found inclinometer technique to be reliable in measurements of the innominate bone inclination. As indicated by these authors, the investigator placed his fingertips through special finger braces mounted on the inclinometer endings. This procedure allowed for palpating the exact landmark concurrently with the moment of reading the outcome. We also assembled a small spirit level

on one arm of the inclinometer to prevent pivoting of the device around the fingertips. The reading was always done with the inclinometer arm positioned directly on the level of the finger contact point. We used a thigh pad, so that the subject could gently support thighs against it and minimize postural sway when measurements were performed. Unfortunately, we had no possibility to use the electronic, liquid crystal display (it was shown by Crowell et al. to be an important feature of the device), which probably caused a slightly lower intra-class correlation coefficient (reported below) obtained in our study.

During the measurements the subjects were asked to wear non-restrictive clothes and to remove their shoes. They placed their feet close to each other, but at a distance that allowed standing in relaxed posture (usually about 10-12 cm). The anterior aspect of the thighs was gently supported by the stabilizing bar. The investigator located the landmarks and marked their position by the color dot on the surface of the skin. This allowed for quick location of the landmark during next step, in which the inclinometer was held in the hand. The subject was asked to gently straighten his knees, stay in contact with the stabilizing bar, and fix his eyesight in a point marked on the wall on the height of 175 cm.

In 33 randomly selected subjects, the measurement was repeated three times and the researcher was blinded to the outcome. After the device had been properly positioned the assistant read the outcome, which was hidden from the researcher.

Statistical analysis

In case of the analysis of numbers the Chi² test was used. Quantitative results were subjected to the logarithmic transformation in order to normalize their skewed distribution. They were then analyzed by using a mixed model of ANOVA with an independent factor (intervention group) and repeated

factor (series of measurements). Post hoc analysis was also implemented using the Tukey test. Repeated measures model of ANOVA was also used for purpose of Interclass Correlation Coefficient calculation. The critical p-level was set at 0.05.

Results

The measurement procedure showed acceptable intra-tester reliability with Intra-class Correlation Coefficients (ICC_{3.1}) of 0.985 (95% CI 0.968-0.993) for the measurements of the innominate bone inclination, and of 0.839 (95% CI 0.721-0.913) for the difference in inclination between right and left sides of the body. Having this last reliability coefficient, we calculated the standard error of measurement of PA of 0.19°. In this case, the difference in observed scores expected on retest (assuming no change of true scores) is 0.27°, and the minimal detectable difference is 0.53°. Taking this into consideration, with the precision of the readout of our device, we decided that a difference of 1° between scores obtained in series 1 and series 2 measurements would be too small to reflect any true change in magnitude of PA. We accepted a change of at least 2° to be a proper cut-off value.

Analysis of numbers

In accordance with our selection criteria we assume that no PA was observed during series 1 measurements. After the mechanical loads had been applied, PA was registered in 23.05% (n=74) of the total group (n=321). Data on the frequency of PA occurrence are presented in Table 2.

In series 2 analysis of the inter-group differences using Chi² test, we showed a significant outcome (p<0.001). The greatest deviations between the observed and expected number frequencies were registered in J.1, P.1 and I.1 groups. Results for the intra-group differences are presented in Table 2.

Table 2

Proportions of pelvic asymmetry registered in the 12 groups during series 2 measurements, together with the p-level of intra-group differences (Chi² test)

Group	J.1	J.2	O.A	R.A	P.1	P.2	I.1	I.2	B.1	B.2	R.1	R.2
percentage of asymmetry	100	19.2	3.4	0	65.4	0	46.1	0	15.4	0	20	3.7
p-level	<0.001	<0.05	>0.05	---	<0.001	---	<0.001	---	<0.05	---	<0.05	>0.05
<u>statistically significant</u>												

Table 3

Mean values, 95% Confidence Intervals (CI) and Standard Deviations (SD) [degrees] of measurements of pelvic asymmetry in series 1 and 2 measurements, together with p-level of intra-group differences (post hoc Tukey test).

Group	series 1			series 2			p-level
	mean	95% CI	SD	mean	95% CI	SD	
J.1	0.24	0.08 – 0.41	0.43	4.65	4.06 – 5.25	1.56	p<0.001
J.2	0.27	0.09 – 0.45	0.45	1.08	0.35 – 1.80	1.79	p>0.05
O.A	0.07	-0.03 – 0.17	0.26	0.28	-0.03 – 0.58	0.80	p>0.05
R.A	0.25	0.08 – 0.42	0.44	0.25	0.08 – 0.42	0.44	p>0.05
P.1	0.38	0.18 – 0.58	0.50	2.92	2.19 – 3.65	1.81	p<0.001
P.2	0.37	0.15 – 0.59	0.56	0.56	0.33 – 0.78	0.58	p>0.05
I.1	0.19	0.03 – 0.35	0.40	1.92	1.15 – 2.70	1.92	p<0.001
I.2	0.42	0.22 – 0.63	0.50	0.46	0.23 – 0.70	0.58	p>0.05
B.1	0.35	0.15 – 0.54	0.48	0.96	0.54 – 1.38	1.04	p>0.05
B.2	0.46	0.23 – 0.70	0.58	0.38	0.15 – 0.61	0.57	p>0.05
R.1	0.32	0.09 – 0.55	0.56	1.04	0.41 – 1.66	1.51	p>0.05
R.2	0.37	0.17 – 0.57	0.49	0.56	0.33 – 0.78	0.58	p>0.05
<u>statistically significant</u>							

Quantitative data

Outcomes of measurements of PA are presented in the Table 3. Analysis of variance showed a significant outcome for interaction of the factors ($F_{(11, 309)} = 29.95$; $p < 0.001$; ANOVA was performed using data after logarithmic transformation). The post hoc analysis revealed no significant inter-group differences in series 1 measurements. In series 2, group J.1 was significantly different from all other groups (all $p < 0.001$), as well as group P.1 (all $p < 0.001$), except when compared with group I.1 ($p > 0.05$). Group I.1 was significantly different from all other groups (all $p < 0.001$, except comparisons with groups P.1 and B.1, J.2 and R.1 ($p > 0.05$)). The data are illustrated in Figure 9 and presented in detail in Table 3.

Discussion

The results of the present study indicate that simple and common mechanical loads are able to trigger PA. The greatest capacity for this was shown when asymmetrical loads were applied in the form of so-called 'mechanical shock' (great force impulse). We call this combination of asymmetrical load and 'mechanical shock' the 'asymmetry formula'. Jump down with landing on one foot (J.1) is a suitable example to illustrate this. It fulfills both components of the formula (i.e., load and shock) and consistently triggers PA in 100% of the subjects. Such a regularity of the formula is exceptional. Jump down with landing on two feet (J.2; symmetrical load), despite its ability to generate 'mechanical shock', did not in-

troduce as much PA. In the J.2 group only one component of the formula was met, and PA was registered in only 21.4% of these subjects. We might assume that at least some subjects in the J.2 group preferred one of their legs when landing, and thereby, produced a slightly asymmetrical loading. This behavior might have been responsible for triggering PA in 19.2% of the J.2 group.

Additional evidence to support our formula emerges from analysis of the asymmetrical resistance exercises and their influence on pelvic configuration. There was no 'mechanical shock' present in these latter trials. The lowest percentage of PA was equal to 15.4%, while the highest was 65.4% (asymmetrical exercise for the *biceps femoris* and *piriformis* muscles, respectively). Muscles originating in the LPHC area, and assuming a 'downward' course, showed a greater capacity to modify configuration of the pelvis (*piriformis*, *iliopsoas*, *rectus* and *biceps femoris* muscles; proportions of triggered PA: 65.4%, 46.1%, 20%, 15.4%, respectively; for comparison – muscles assuming an 'upward' course: *rectus abdominis* muscle 0%, *obliquus abdominis* 3.4%). Similarly, so were muscles locating both attachments in the LPHC region: *piriformis* and *iliopsoas* at 65.4% and 46.1% of triggered PA, respectively; for comparison – muscles affecting distant joints: *rectus femoris* 20%, *biceps femoris* 15.4%).

No potential to trigger PA was registered when none of the formula components were fulfilled (symmetrical resistance exercises). Either there was no asymmetry at all or it appeared in single subjects only (Table 5).

Taking all the above items into consideration it seems reasonable to propose the asymmetry formula as follows:

$$\text{pelvic asymmetry} = \text{asymmetrical load} + \text{mechanical shock}$$

Data supporting the formula are given in Table 4. Results of inclinometer measurements of PA also support the formula. The largest magnitude of PA was registered in the J.1 group. Asymmetrical, resistance exercises of the muscles with both attachments in the LPHC area had the second largest PA impact (P.1 and I.1 groups), whereas the least impact on PA was seen in subjects performing symmetrical jump down (J.2 group), together with subjects performing asymmetrical resistance exercises of the long biarticular muscles (B.1 and R.1 groups). Small magnitudes of PA were registered when none of the formula components were met (Table 3).

It is not surprising that PA appears simultaneously with the mechanical load. Such a phenomenon is commonly observed in gait analyses. Analysis of gait determinants reveals that the pelvis tends to assume asymmetrical configuration of a torsional type in the heel contact phase. PA persisting after mechanical loading has completed attracts more attention. In our opinion, mechanical forces are not solely responsible for these observations, but rather neurophysiological control processes are also affected. Tullberg et al. (1998) demonstrated that PA may be eliminated manually with no significant change in sacroiliac joint position. According to these authors, a mechanical force directed to the pelvis is only a source of input information to the control system, where it produces a specific 're-set' feature, and re-executes a symmetrical tension pattern, which is observed in the activity of effectors. This process likely also takes an opposite direction. Asymmetrical muscle loading provides the necessary input information to introduce 'system error' and thereby, initiates execution of an asymmetrical tension pattern. One re-

port of a slightly different character has already indicated the possibility of influencing the control system through mechanical loading of the pelvis (Marshall & Murphy, 2006). On the other hand, Moseley & Hodges (2005) report that even short-term exposure to a disturbing stimulus is able to alter the control processes in the long term.

Hopefully, no impression has been given that after mechanical loading, the subjects in whom PA was triggered were left to their own devices. The experiment by Tullberg et al. (1998), together with our previous studies (Gnat et al. 2004ab), clearly indicate that PA which has persisted longer than the triggering mechanical load, can easily be eliminated by means of manual stretching--mobilizing techniques directed to the sacroiliac joints and surrounding soft tissues. PA itself, and all associated functional alterations, were immediately eliminated in this way. These observations support the remarks concerning interaction between mechanical loading and neurophysiologic processes proposed above. Our data in this area of the experiment were published elsewhere (Gnat et al. 2008).

The arguments mentioned above suggest that the phenomenon of PA can be divided into two types: 'fresh' asymmetry, which is typical for activities of daily living and introduced by common loads (such PA observed in the present study), and 'cemented' asymmetry, which is resistant to correction and frequently accompanied by symptoms within the LPHC (pathology-linked PA). In case of long-term functional asymmetry, the tissues are inevitably subjected to exaggerated tension, which may start accumulation of asymmetrical overload and produce subjective symptoms within the locomotory system.

It should also be noted that PA may be observed before any subjective symptoms of dysfunction are present; therefore, symptomology is a valuable and easily assessed sign of latent insufficiency. Its evaluation is linked to the essence of the common

Table 4

Proportions of pelvic asymmetry in the 12 groups during series 2 measurements. Fulfilment of both components of the 'asymmetry formula' gives the highest possibility of modification of pelvic configuration

Group	J.1	J.2	O.A	R.A	P.1	P.2	I.1	I.2	B.1	B.2	R.1	R.2
Asymmetry												
AL	+	-	+	-	+	-	+	-	+	-	+	-
MS	+	+	-	-	-	-	-	-	-	-	-	-
percentage of asymmetry	100	19.2	3.4	0	65.4	0	46.1	0	15.4	0	20	3.7
statistically significant												

adage: prevention is better than cure. PA is an indication that our preventive efforts should be doubled, like a yellow light at the crossroads. Such a diagnostic tool could be invaluable for every physiotherapist, physician, coach or physical education teacher.

Regarding the limitations of the present study, the mechanical loads applied (except jumps) do not fully reflect the motor tasks of daily living. However, they are very simple forms of motor activity, that are encountered by each individual, perhaps not every day, but certainly during trainings in fitness clubs, scheduled sport exercises, etc. (all subjects were students of a university school of physical education). Lack of quantification of the applied loads may also be problematic. The resistance that was manually applied by the therapist has, however, certain advantages. It could be quickly adjusted to the subject's strength, so in each set and repetition the true sub-

maximal level was reached. Although considerable physical effort was warranted, the performance remained technically clear and utilized the full range of motion. The therapist was also able to adjust the direction of the resistance, so that it was always perpendicular to the long axis of the limb. Such a goal would be difficult to achieve by means of mechanical devices producing quantifiable resistance. Lastly, no control group was employed in this study, which also leaves the possibility of some additional bias.

Conclusion

Pelvic asymmetry appears very frequently as a consequence of mechanical loading of the pelvis. In this light, it should be perceived as a physiologic alteration that adapts the locomotory system to the transmission of asymmetrical mechanical loads.

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Acknowledgments

Authors would like to acknowledge financial and organizational help of the company Meden-Inmed, Medical Engineering, Koszalin, Poland

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