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ORIGINAL RESEARCH

Static pelvic asymmetry is not linked to activation asymmetry of the lateral abdominal muscles and body weight distribution asymmetry on lower extremities

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Abstract

Background: Pelvic, spinal and hips asymmetries constitute common phenomena. Pelvic asymmetry is usually perceived from two different points of view: as a causative factor in certain motor system dysfunctions or as a symptom of existing dysfunctions. **Objective:** This study aimed to evaluate the difference in activation asymmetry of lateral abdominal muscles (LAM) and the difference in body weight distribution on lower extremities during prolonged standing between subjects with and without pelvic asymmetry, and check if there is a correlation between the magnitude of pelvic asymmetry and activation asymmetry of lateral abdominal muscles as well as body weight distribution on lower extremities. **Methods:** A total of 66 subjects (34 women) participated in the study. LAM activation was measured using ultrasound technology. Body weight distribution asymmetry on lower extremities was measured during prolonged barefoot standing on the two scales equipped with digital readings. The activation asymmetry index and the weight distribution asymmetry index between the left and right sides of the body were calculated. **Results:** The recorded weight distribution asymmetry indexes were slightly higher in subjects with pelvic asymmetry; however, no significant inter-group differences were found. These subjects did not show any significant difference from subjects without asymmetry for activation asymmetry index recorded in all individual LAMs (obliquus externus abdominis p = .68, obliquus internus abdominis p = .34, transversus abdominis p = .55). **Conclusions:** No differences were found between subjects with and without pelvic asymmetry in activation asymmetry of lateral abdominal muscles and body weight distribution on lower extremities. Thus, there was no evidence gathered to prove that pelvic asymmetry constitutes an advantageous or disadvantageous phenomenon. It seems that it may play only a minor role, if any, in the energy expenditure optimisation process during prolonged standing. It is unlikely that pelvic asymmetry may lead to or stem from activation asymmetry of lateral abdominal muscles.

Keywords: pelvis, ultrasound, lateral abdominal muscles, asymmetry, body weight distribution

Introduction

Pelvic, spinal and hips asymmetries constitute common phenomena (e.g., Badii et al., 2003; Gnat & Biały, 2015; Gnat et al., 2009; Jung et al., 2015, Yu et al., 2020). Pelvic asymmetry is usually perceived from two different points of view: as a causative factor in certain motor system dysfunctions or as a symptom of existing dysfunctions. In the case of scoliosis, pelvic asymmetry is regarded as a sign of secondary compensation (Appelbaum et al., 2021), it frequently accompanies the leg length discrepancy (Jung et al., 2015; Teles et al., 2020). In the field of manual therapy, it is traditionally treated as a symptom of sacroiliac joint dysfunction (DonTigny, 1985; Stoddard, 1959), where it exerts influence on the soft tissue tension/relaxation patterns and catalyses the development of overload syndromes (Cibulka et al., 1998; Schamberger, 2002).

In many instances, pelvic asymmetry occurs in healthy populations with no dysfunctional symptoms (Badii et al., 2003; Gnat et al., 2009). According to these authors, the asymmetry should be regarded as either a physiologic phenomenon associated with force transmission optimisation between the trunk and lower extremities, or a first noticeable symptom of overload syndromes, emerging already in *insufficientia latens* stage of the overload yet in the absence of other functional abnormalities or pain. In some cases, pelvic asymmetry seems to constitute a temporary issue, easy to be introduced and easy to be removed using, for example, simple manual therapy techniques (Dębski et al., 2019; Gnat et al., 2009; Kuszewski et al., 2018). In others, it is of a persistent nature supported by the natural lateralization of the body and/or by stereotypic daily-life motor patterns (Gnat et al., 2009).

In this particular study, we support points of view showing pelvic asymmetry as a manifestation of the energy optimisation process of an erect standing position. It is possible to prove mathematically that modification of

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sacroiliac joint inclination angle in the asymmetric pelvis influences the mechanisms of pelvic form and force closure as described by Snijders et al. (1993a, 1993b) and Vleeming et al. (1997, 1990a, 1990b). More horizontal alignment of the joint surfaces on one side of the body reduces the magnitude of sharing forces loading the joint. Moreover, such an alignment increases friction between the joint surfaces. All this may be perceived "asymmetrically advantageous" arrangement from the perspective of body weight distribution on lower extremities and may result in a preference for distribution towards one lower extremity when maintaining the erect position, especially during prolonged periods of time.

On the opposite side of the body, in a more vertically aligned sacroiliac joint, friction deficiency and excessive shearing forces must be compensated differently, in other words, by an intensification of the force closure mechanism of the joint. This mechanism is executed by means of activation of certain core muscles, for example, oblique and transversus abdominis, pelvic floor (Pool-Goudzwaard et al., 2004; Snijders et al., 1995). Asymmetric engaging of the force closure mechanism in one sacroiliac joint should hypothetically produce signs of asymmetric activation of mentioned muscles. Core muscles are of special importance since disorganisation of their physiologic mode of activation was shown to be linked to low back pain including idiopathic pain of uncertain origin. This disorganization is manifested either as minor temporal shifts of local muscle activation in relation to other muscles (Hodges & Richardson, 1998, 1999; Hungerford et al., 2003; O'Sullivan et al., 1997; Vasseljen & Fladmark, 2010) or as decreased variability of muscle activation timing (Biały et al., 2019; Jacobs et al., 2009; Moseley & Hodges, 2005, 2006).

To summarize, it is difficult to unambiguously judge: is pelvic asymmetry an advantageous or harmful phenomenon for the organism? It seems that initially, adequate strategy promising energy cost optimisation with time introduces the risk of tissue overuse, dysfunction and pain. Empirical verification of the hypothetic correlations between pelvic asymmetry and asymmetry of core muscles activation as well as asymmetry of body weight distribution on lower extremities would surely help in understanding these processes. In this light, the aims of this study were: 1) to evaluate possible differences in activation asymmetry of lateral abdominal muscles (LAMs; partially representing core muscles, i.e., transversus abdominis, obliquus internus abdominis) between subjects with and without pelvic asymmetry; 2) to evaluate possible differences in body weight distribution on lower extremities during prolonged standing between subjects with and without pelvic asymmetry; 3) to assess the correlation between the magnitude of pelvic asymmetry and activation asymmetry of lateral abdominal muscles as well as body weight distribution on lower extremities.

Methods

Participants

Hundred-and-one adult subjects volunteered to participate and were tested against the selection criteria. The inclusion criteria were: age below 40 years (before intensification of the degenerative processes in the 5th decade of life); static pelvic asymmetry of ≥ 4.0° (based on recommendations by Gnat and Biały (2015), doubled minimal detectable difference) in the asymmetry group (A group) and ≤ 2.0° in the symmetry group (S group). The exclusion criteria were: history or current diagnoses of any serious orthopaedic or neurologic conditions (e.g., fractures, congenital deformations, cerebral palsy and other developmental conditions with a clear diagnosis, etc.); history of any surgical and orthotic interventions; history of serious musculoskeletal pain and dysfunction (of more than two-week duration, requiring medical/physiotherapeutic assistance), or any recent (one month prior to the experiment) musculoskeletal pain and dysfunction; minor maladies on the day of measurement (cold, headache, excessive fatigue, etc.); excessive fat mass precluding ultrasound measurement of LAM thickness and accurate palpation of pelvic anatomical landmarks (body mass index higher than 24 kg/m^2).

Twenty-nine subjects did not fit into the described limits of pelvic asymmetry, seven showed a history of fractures, three had a history of surgical interventions within the abdominal area, five had a history of recent minor injuries and seven had excessive body mass index. Sixty-six subjects (34 women) qualified for the study received detailed information on the objectives and procedures. They formed two study groups – the A group and the S group based on the magnitude of static pelvic asymmetry. There were no dropouts during the study. Characteristics of the groups are presented in Table 1.

Table 1 Means (standard deviations), ranges, and *p*s for the basic groups characteristics

Variable	Symmetry group	Asymmetry group	*p*[a]
Gender	11 males 14 females	21 males 20 females	.38
Age (years)	23.48 (5.15) 20–37	25.96 (4.59) 20–40	.42
Body height (cm)	170.94 (7.84) 158–195	173.25 (5.46) 164–190	.51
Body mass (kg)	63.57 (10.64) 49–87	66.23 (8.16) 50–84	.48
Body mass index (kg/m^2)	21.88 (1.18) 19.63–23.67	22.15 (1.21) 18.60–23.27	.64

Note. [a]Chi-squared test was used for gender and Mann-Whitney *U* test for the rest of the variables.

All participants have signed their informed consent. The study was approved by the institutional Biomedical Research Ethics Committee and was conducted in accordance with the novel of the Helsinki Declaration of 2013.

Measurements

Evaluation of the pelvic asymmetry was performed using the method developed previously by Gnat et al. (2009). In this method, the angle of inclination of the line joining the two anterior superior iliac spines in relation to the horizontal line is determined (Figure 1). An angle equal to 0° indicates a symmetrical arrangement of the pelvis. A hand inclinometer (Palpation Meter PALM, Performance Attainment Associates, St. Paul, MN, USA) was used with a precision of ± 1° (Figure 1). The subject was positioned upright with both feet placed close together, and sight fixated on one point at eye level. After the relevant anatomical landmarks had been found (without observing the scale of the inclinometer) the researcher gave the command "ready" and the second person read the reading of the device. This procedure was repeated three times and the mean value of these three measurements was taken into further consideration. The measurement procedure showed acceptable intra-rater reliability with intraclass correlation coefficients of 0.831 (Gnat et al., 2009), standard error of measurement of 0.51° and smallest detectable difference of 1.81°.

To evaluate LAM activation and activation asymmetry various approaches are in use (Biały et al., 2017, 2019), including the indirect ultrasound methods. In this particular study, ultrasound technology was employed, too (two Mindray DP660 devices, Mindray, Shenzhen, China, with 75L38EA probes), using Gnat et al. (2012) methodology. B-mode images showing three layers of LAM (obliquus externus [OE], obliquus internus [OI], transversus abdominis [TrA]) were bilaterally recorded in the relaxed supine position (three repeated measurements) and during abdominal bracing manoeuvre (three repeated measurements) (Richardson et al., 2002; Tayashiki et al., 2016; Figure 2). The thickness of all LAM on the right and left sides of the body were measured in these

Figure 1 Left: Schematic drawing of the employed method of pelvic asymmetry measurement (see also Gnat et al., 2009). The recorded angle of inclination of the line connecting the two anterior superior iliac spines (ASIS) in relation to horizontal is shaded grey. The angle equal to 0° indicates symmetrical arrangement of the pelvis. Right: Palpation meter PALM (Performance Attainment Associates, St. Paul, MN, USA).

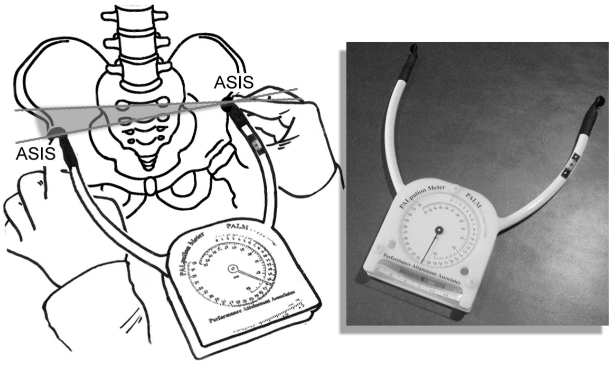
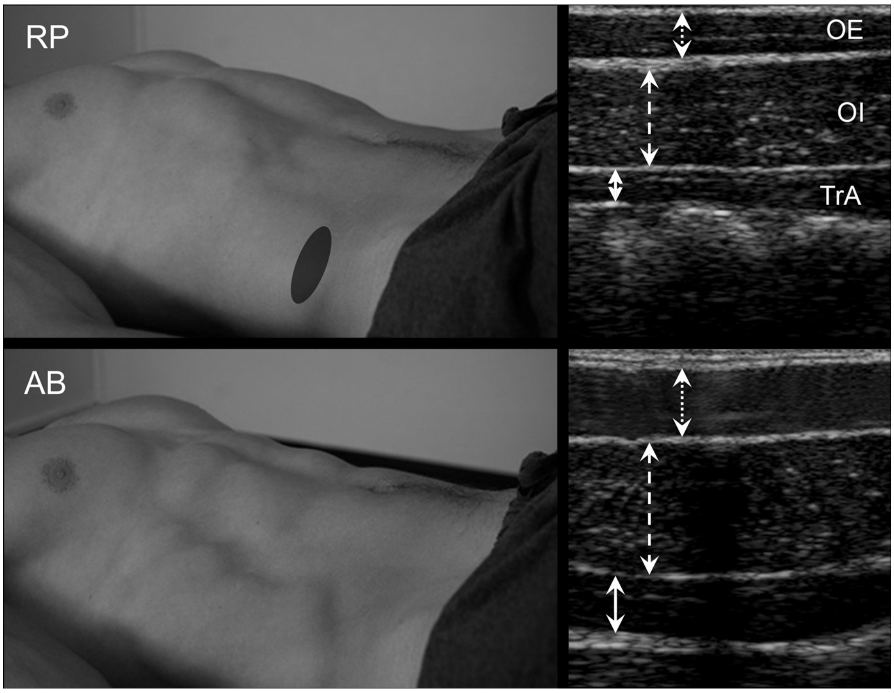


Figure 2 Left: Abdominal musculature. Right: Ultrasound image of lateral abdominal muscles in resting position (RP) and during abdominal bracing manoeuvre (AB).



Note. OE = obliquus externus abdominis; OI = obliquus internus abdominis; TrA = transversus abdominis. Grey oval indicates approximate location of the ultrasound probe. One location is shown; in fact two probes of two devices were used simultaneously and symmetrically on two sides of the trunk. Arrows on the right images indicate thicknesses of particular lateral abdominal muscles. All thicknesses increase during AB.

two conditions and subjected to further data processing. Previous research showed that these measurements present an acceptable level of reliability (Gnat et al., 2012) and they are valid indicators of LAM activation based on their strong correlation with electromyographic signal from LAM (Vasseljen et al., 2009). Before the procedure, the subjects were trained to perform the demanded manoeuvre under the supervision of the ultrasound feedback. The required thickness changes of the individual muscles allowing for qualification as a proper performance were: > 50%, > 30% and > 50% of the resting thickness, respectively for OE, OI and TrA (Gnat et al., 2020). After training (see below) we found no problems with the proper execution of the abdominal bracing with the maintenance of muscular contraction for the time allowing to capture the ultrasound image.

In order to evaluate body weight distribution asymmetry on lower extremities subjects were asked to maintain the unrestricted upright position for one hour while standing barefoot on the two scales equipped with digital readings. The prolonged time of the measurement served to introduce fatigue and evoke versatile strategies of maintaining the demanded body arrangement. It was not allowed to lose contact of any foot with the scale, to extensively bend the trunk or to support hands against thighs, etc. Except for this the subjects were free to load their lower extremities in their preferred manner. The readings of both scales were recorded using the camera located behind the subjects, so they were not disturbed by this fact. They did not have any visual contact with the readings. After the measurement the recorded video material was analysed and readings of the two scales were read every 30 seconds.

Procedure

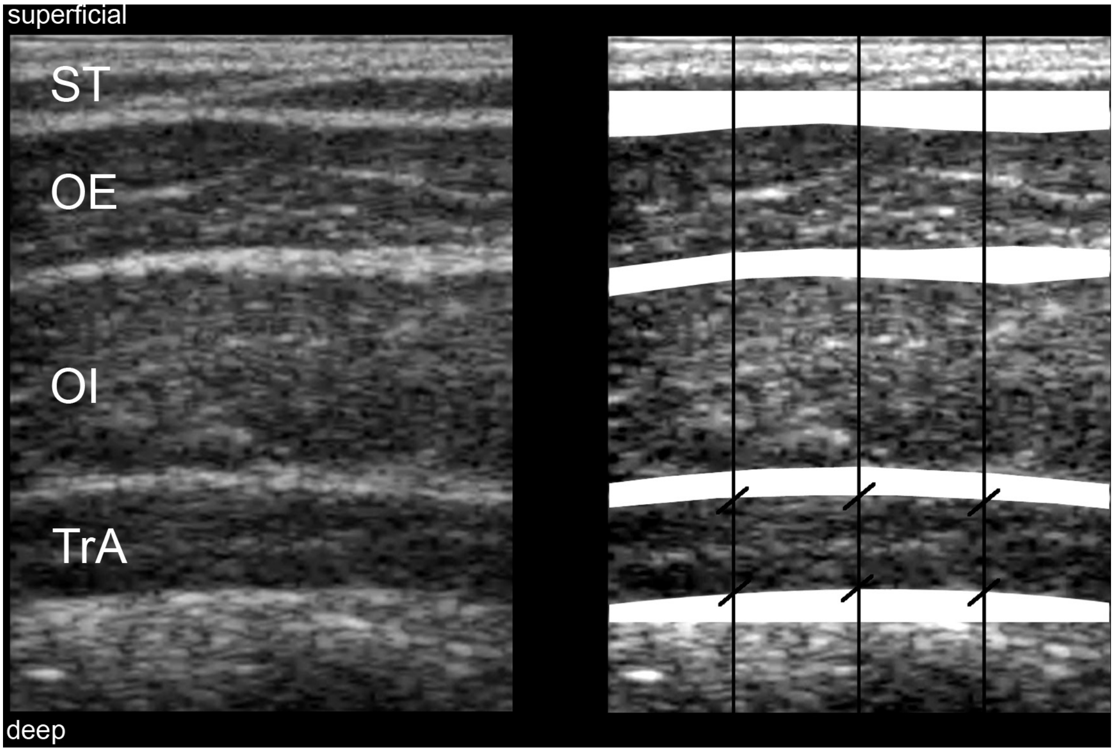
After the recruitment procedures (including the pelvic asymmetry measurement) all qualified subjects were trained as far as the abdominal bracing manoeuvre is concerned. A convenient date for the measurements was found within 2–3 days after that. The subject presented themselves wearing non-restricting clothes. Measurements of the LAM thickness were performed in following by measurements of the load distribution asymmetry on the lower extremities. The whole procedure consumed about 1.5 hours. It was completed by all subjects.

Data processing

Lateral abdominal muscles activation asymmetry index

After completing the measurement procedure, we gathered three images of the LAM in the relaxed position and three images during abdominal bracing for both the left and right sides of the body. The thickness of each individual LAM in each condition was measured as described in detail by Gnat et al. (2012) and others (Gogola et al., 2016, 2018; Polaczek & Szlachta, 2023; see Figure 3). The mean thickness measured on all three images in the relaxed position

Figure 3 Left: Raw real-time ultrasound image of the lateral abdominal muscles. Right: An image after editing (see also Gnat et al., 2012) showing three layers of lateral abdominal muscles.



Note. OE = obliquus externus abdominis; OI = obliquus internus abdominis; TrA = transversus abdominis. Layers of intermuscular fasciae are shaded white. As an example, TrA thickness was measured along the three black lines depicted on the edited image. The mean value of these three measurements was subjected to further analysis. Thickness of the two remaining muscles was measured accordingly. Each of the three images recorded in the relaxed position and of the three images recorded during abdominal bracing were treated in accordance to this procedure.

and three images during abdominal bracing was subjected to analysis.

First, the percent thickness change of each individual LAM, separately on the left and right sides of the body was calculated according to the formula:

$$TC = (TR - TB) \times 100\% / TR$$

where TC is thickness change, TR is thickness in a relaxed position, and TB is thickness during abdominal bracing.

Second, the activation asymmetry index (AAI) between the left and right sides of the body was calculated according to the formula:

$$AAI = |(TCl - TCr)| \times 100\% / |(TCl + TCr)|$$

where AAI is activation asymmetry index, TCl is thickness change recorded for the given left LAM, and TCr is thickness change recorded for the given right LAM.

The AAI calculated this way depicts the magnitude of the activation asymmetry, not the sidedness of this asymmetry.

Weight distribution asymmetry index

In total, 120 readings of the left scale and 120 readings of the right scale were collected (every 30 seconds). The weight distribution asymmetry index (WDAI) between the left and right sides of the body for each pair of readings was calculated in accordance with the formula:

$$WDAI = |(R - L / R + L)| \times 100\%$$

where R is the right scale reading and L is the left scale reading.

The WDAI calculated this way depicts the magnitude of the load distribution asymmetry, not the sidedness of this asymmetry. As a result, a set of 120 WDAIs was collected. In the next step, the mean WDAIs were calculated for each 10-minute periods: $WDAI_1$ = mean WDAI 1–20, $WDAI_2$ = mean WDAI 21–40, $WDAI_3$ = mean WDAI 41–60, $WDAI_4$ = mean WDAI 61–80, $WDAI_5$ = mean WDAI 81–100, $WDAI_6$ = mean WDAI 101–120. Finally, the total WDAI for the whole 1-hour measurement procedure (tWDAI) was computed as mean WDAI 1–120.

Statistical analysis

Data analyses were performed using Statistica (Version 13; StatSoft, Tulsa, OK, USA). Distributions of the variables within the groups were evaluated using the Shapiro-Wilk test. Due to very frequent deviations from a normal distribution (right-side skewness in most cases), non-parametric analysis was introduced. Inter-group differences between WDAIs and AAIs were tested using the Mann-Whitney *U* test. Intra-group differences between consecutive WDAIs, in other words, $WDAI_1$ to $WDAI_6$, were assessed using Friedman analysis of variance (ANOVA), followed by its own post hoc test (post hoc for Friedman ANOVA). The differences in AAI between individual LAM (i.e., inter-muscle differences) were evaluated employing Kruskal-Wallis ANOVA, followed by its own post hoc test (multiple comparisons for Kruskal-Wallis ANOVA). Correlations were assessed using the Pearson correlation coefficient based on its high robustness to deviations from distribution non-normality (Portney & Watkins, 2009). The critical *p* level was set at .05.

Results

Pelvic asymmetry

The recorded values of pelvic asymmetry, in the S and the A groups were 1.56º (± 0.49) and 5.69º (± 1.15) on average.

Weight distribution asymmetry indexes

The recorded WDAIs were slightly higher in the S group, however, no significant inter-group differences were found (including tWDAI; Table 2). High variability of all WDAIs is visible with standard deviations frequently exceeding their mean values. In both groups, similar tendencies in consecutive WDAIs' were recognised. The indexes systematically increased showing their maxima between minutes 30–40 of measurements in the S group and between minutes 40–50 in the A group. Towards the end of the measurement, the WDAIs decreased again in both groups. With time, significant intra-group differences (post hoc test for Friedman ANOVA) occurred. They were $WDAI_1$ vs. $WDAI_4$ ($p < .01$), $WDAI_5$ ($p = .03$), $WDAI_6$ ($p = .03$); $WDAI_2$ vs. $WDAI_4$ ($p = .05$) in the S group, as well as $WDAI_1$ vs. $WDAI_5$ ($p = .04$), $WDAI_6$ ($p = .03$); $WDAI_2$ vs. $WDAI_5$ ($p = .04$), $WDAI_3$ vs. $WDAI_5$ ($p = .05$) in the A group.

Table 2 Means (standard deviations), ranges, and *p*s for the load asymmetry indexes (in percents)

Variable	Symmetry group	Asymmetry group	*p*
tWDAI	18.19 (21.15) 2.83–73.59	18.49 (16.32) 2.98–56.07	.69
$WDAI_1$	9.65 (15.86) 1.56–58.45	13.80 (10.95) 3.59–40.95	.42
$WDAI_2$	13.69 (20.80) 1.69–75.52	16.22 (13.91) 2.19–50.08	.37
$WDAI_3$	17.56 (20.79) 4.85–72.76	16.63 (14.76) 2.84–47.79	.66
$WDAI_4$	25.29 (23.45) 4.40–82.24	17.83 (17.60) 2.89–57.67	.25
$WDAI_5$	22.68 (24.14) 2.40–82.93	23.95 (19.98) 3.43–68.20	.61
$WDAI_6$	20.29 (21.86) 2.08–69.64	22.51 (20.73) 2.50–71.72	.47

Note. WDAI = weight distribution asymmetry index, tWDAI = total WDAI for the whole 60-minute measurement; $WDAI_{1...6}$ = WDAIs for the six consecutive 10-minute periods.

Activation asymmetry indexes

Statistics for AAI recorded in all individual LAM are presented in Table 3. The S group did not show any significant difference from the A group. The indexes showed a characteristic gradient with the TrA being the most asymmetric and the OE the least. The differences between individual LAM were significant (post hoc test for Kruskal-Wallis ANOVA) between OE vs. TrA (p = .04) in the S group, as well as between OE vs. TrA (p = .03) and OI vs. TrA (p = .05) in the A group.

Correlations

As far as WDAIs are concerned, the correlation coefficients were slightly higher in the A group. The highest were r = .25 (weak, p > .05) between the magnitude of pelvic asymmetry and the $WDAI_4$ in the A group.

For AAIs, the highest correlation coefficient of r = .37 (weak, p > .05) was recorded between the magnitude of pelvic asymmetry and AAI of the TrA in the A group.

All remaining coefficients were smaller and, similarly, non-significant.

Discussion

This study places itself between discussions on whether and to what extent the asymmetry of the human body might be regarded as physiological. We assumed that one particular symptom of the body asymmetry, in other words, pelvic asymmetry, may initially constitute a manifestation of physiologic energy optimisation processes. This assumption was based on the fact that pelvic asymmetry occurs frequently in healthy populations (Badii et al., 2003; Gnat et al., 2009) and on calculations showing that in an asymmetrical pelvis, the energy-saving form closure mechanism may be promoted in one sacroiliac joint (Snijders et al., 1993a, 1993b; Vleeming et al., 1990a, 1990b, 1997). In the next step, we tried to examine associations between the pelvic asymmetry and other signs of asymmetry within the lower quarter of the body, in other words, activation asymmetry of LAM and weight distribution asymmetry on lower extremities, which seem to be burdened with some pathologic potential (e.g., low back pain, overload syndromes within the lower quarter; Biały et al., 2019; Cibulka et al., 1998; DonTigny, 1985; Hodges & Richardson, 1998; Hodges & Richardson, 1999; Hungerford et al., 2003; Jacobs et al., 2009; Moseley & Hodges, 2005, 2006; O'Sullivan et al., 1997; Vasseljen & Fladmark, 2010), especially from the long term perspective. This way we wanted to establish the path over which the non-symptomatic and non-pathologic pelvic asymmetry leads to tangible pathologies.

The presented theoretical construction and our research questions did not find confirmation in the course of the study. No significant correlations were found between the magnitude of pelvic asymmetry and WDAIs as well as AAI in both S and A groups. In the A group the calculated correlation coefficients were slightly higher (maximal Pearson's r of .37) and more regular (all correlations were positive). Nonetheless, they may only be classified as weak correlations and none of them showed any statistical significance. Moreover, no significant differences were revealed between the A and S groups, as far as AAIs and WDAIs values are concerned. In light of the current results the pelvic asymmetry, activation asymmetry of the LAM and weight distribution on lower extremities do not seem to be interrelated with each other. They rather constitute manifestations of different processes taking place within the organism. Each of these processes carries its own, potential threats to the human motor system. Therefore, our observations stand in opposition to the claims of others, suggesting that symptoms of structural or functional skeletal asymmetry (including pelvic asymmetry) may be linked to the function of the TrA and other abdominal muscles (Kuszewski et al., 2018). Although valid explanations are provided by the authors (in fact these explanations partially inspired us to develop the theoretical background of our study), our results do not support these claims. It seems safer to regard them as speculations more than facts.

It is, however, worth noticing, that in statistical terms we are not entitled to claim there is no relation between the key variables in the study, but that we were unable to prove a significant relationship exists. This is not tantamount to the actual lack of the relation, which could be revealed with larger study groups.

Besides that, a piece of useful knowledge is still present in the results of the study. First, our earlier findings concerning activation asymmetry of the LAM as well as the findings of other authors were quite strongly confirmed. We recorded a relatively high magnitude of AAIs (35–59% on average) and a characteristic gradient of AAI, with TrA showing the biggest asymmetry (56–59% on average, maximally 193%) and OE – the lowest (35–37% on average, maximally 81%). Moreover, TrA showed the most variable level of activation in comparison with other LAMs (ranges of 184% in the S group and 191% in the A group). This is in line with the results of Biały et al. (2019), Gnat and Biały

Table 3 Means (standard deviations), ranges, and ps for the lateral abdominal muscles activation asymmetry indexes (in percents)

Muscle	Symmetry group	Asymmetry group	p
Obliquus externus abdominis	37.01 (19.58) 4.51–76.02	35.15 (21.12) 3.78–81.01	.71
Obliquus internus abdominis	46.11 (23.22) 3.98–120.09	40.95 (25.03) 2.87–115.12	.43
Transversus abdominis	56.10 (51.12) 0.97–185.56	59.55 (55.16) 2.04–193.23	.64

(2015), Gnat et al. (2020), Gogola et al. (2016, 2018), Kim et al. (2013), and Polaczek and Szlachta (2023).

As far as WDAI is concerned, a specific, uniform motor behaviour of the subjects was revealed. In both S and A groups the calculated WDAIs increased up to 40.–50. minute of the measurement (maximally to 83%) and then – decreases again as if the motor system tried to find the optimal strategy to manage the body weight transmission to the lower extremities. Perhaps, after going too deep into the asymmetry it finally moved back towards a more symmetric arrangement. Whether or not this observation might be called "a strategy" remains an open question and needs further investigation. It is difficult to compare this finding with other data since, up to date, we were unable to find any studies employing measurement of body weight distribution during prolonged (1 hour) standing. However, we want to underline the value of such measurement and we submit our data for discussion with other similarly oriented authors.

Our study shows several inherent limitations that we are aware of and we would like to acknowledge to the reader. Among the limitations we place is the fact that in our theoretical considerations, we addressed energy optimization processes without subjecting energy expenditure to direct measurement. Such an approach may build a convenient base for further experiments. The measurements of LAMs activation were also indirect, via ultrasounds, which is supported by acceptable correlations of the electromyographic and ultrasound signals (Vasseljen et al., 2009), however, might be questioned. We also claim that in favor of our research questions would be the development of a technology in which magnitudes of pelvic asymmetry, activation asymmetry of the LAM and weight distribution asymmetry on lower extremities are measured simultaneously, in a real-time fashion. This suggestion will create a foundation for our further pursuits. Our results are limited to relatively slim and fit subjects, too. Due to the nature of our measurements and following the selection procedure we used the words "relatively slim and fit" in our research announcement. Probably, this made "slim and fit" persons more likely to volunteer, and finally moved body mass and body mass index towards lower values. Inclusion of other populations, including clinical with, for example, low back pain symptoms, is also to be considered. Despite limitations, we would also like to acknowledge the high-reliability indices of all our measurements, which emphasize their credibility.

Conclusions

No differences were found between subjects with and without pelvic asymmetry in 1) activation asymmetry of lateral abdominal muscles; and 2) body weight distribution on lower extremities. No significant correlations were revealed between the magnitude of pelvic asymmetry, activation asymmetry of lateral abdominal muscles and body weight distribution on lower extremities. No evidence was gathered to prove that pelvic asymmetry constitutes an advantageous or disadvantageous phenomenon. It seems that it may play only a minor role, if any, in the energy expenditure optimisation process during prolonged standing. Moreover, it is unlikely that pelvic asymmetry may lead to or steam from activation asymmetry of lateral abdominal muscles.

Conflict of interest

The authors report no conflict of interest.

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