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Impact of physical activity on postural stability in pregnant and postpartum women

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ABSTRACT
Purpose. Regular physical activity is recommended by the WHO for women in the perinatal period as one of the basic factors determining the physiological course of pregnancy, childbirth and the postpartum period. The study aimed to identify the relationship between regular physical training of pregnant women, carried out in the second and third trimesters of pregnancy, and postural stability during the perinatal period.
Methods. 58 women in the first trimester of pregnancy took part in the study and were divided into two groups according to their own choice. The exercise group participated in physical training three times a week during the second and third trimesters of pregnancy. The non-exercise group did not engage in additional physical activity. All subjects underwent three postural stability tests using a stabilograph.
Results. In assessing posture stability parameters, significant differences were found only in body coordination in the active group of women. The exercise group showed statistically significantly lower values of the stabilogram parameters (better postural stability) obtained postpartum compared to those taken during pregnancy. There were no significant differences between the results taken during pregnancy. In the group of non-exercising women, no significant differences were observed between the second measurement during pregnancy and the measurement made postpartum.
Conclusions. It has been shown that physical activity has a significant impact on improving the coordination of women during pregnancy and postpartum. Women participating in regular physical training were characterised by smaller stabilogram deflections and better postural control compared to the control group.
Key words: physical activity, postural stability, pregnancy, stabilography, posturography

Introduction

The decision regarding regular physical activity and monitoring the health of a pregnant woman is most often taken by the attending physician and other medical personnel. Therefore, the medical personnel must know the standards of perinatal care during regular contact with a pregnant woman. Consequently, it seems necessary to popularise scientific research on the role of physical activity in pregnant women as well as detailed guidelines, indications and contraindications. In their 2018 work, Harrison et al. [1] scoured popular databases for results that turned out to be surprising. After more than 15 years of diverse studies on pregnant uniform populations, consistent results have not been achieved [1]. Therefore, it is recommended to design and perform studies based on objective research techniques and methods as well as extensive statistical analysis. The World Health Organization and many national and international health organisations recommend prenatal physical activity as one of the basic factors determining the physiological course of pregnancy, childbirth and the postpartum period [2–7].

The latest recommendations of Canadian specialists point out increasing physical activity during pregnancy in terms of exercise time and the number of training sessions per week. After a thorough analysis of the results of previous studies and recommendations, the positive impact of exercise on the mother and child's physical and mental health was confirmed. It has been shown to reduce the risk of pre-eclampsia, gestational diabetes, pregnancy-induced hypertension, caesarean sections and surgeries, urinary incontinence,

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excessive weight gain and depression. The adverse effects of training on the health of the pregnant woman, foetus and newborn have not been confirmed. Regular physical activity is not associated with miscarriage, premature birth, neonatal death, low birth weight or developmental defects and does not cause perinatal complications [5]. Excessively strenuous, high-frequency or high-intensity exercise was not encouraged. While promoting physical activity during pregnancy, three or more moderate-intensity training units per week were proposed. Recommendations cover various forms of activity: aerobic exercises, resistance exercises, stretching exercises and yoga [8].

Improving balance and coordination parameters reduces, but does not exclude, the risk of falling during physical or daily activities. Sources in the medical literature discuss cases of, for example, amniotic band syndrome (rupture of the amniotic sac), placental detachment, and miscarriage, all of which may have an underlying cause resulting from a fall or trauma [9]. Therefore, controlled physical activity for pregnant women is characterised by an assurance approach with increased caution. Contact or shock-absorbing sports are not recommended. Czarnecki et al. [10] recommend, for example, stationary cycling rather than off-road cycling.

Types and forms of physical activity during individual and group training are often combined. Depending on the state of health and well-being of the pregnant woman and several systemic changes, exercises used in individual trimesters have their specific assumptions. Nevertheless, they share a common goal: to maintain well-being and an optimal state of fitness. Therefore, training recommendations should be, above all, safe and appropriate for the stage of pregnancy. Extreme sports and those that involve the risk of falling or injury, as well as those that are too intense, are excluded [11].

Sytsma et al. [12] define the first trimester of pregnancy as the least stable period for undertaking physical activity, arguing that this is due to the intensification of pregnancy symptoms, such as nausea, vomiting and others. The paper describes several concerns about exercise in the first trimester of pregnancy, which are motivated by malaise or a lack of regular activity before pregnancy. General development exercises and exercises preparing the body for changes that will soon appear and increase with the advancement of pregnancy are introduced in the first trimester. If a pregnant woman led an active training lifestyle until pregnancy, she often did not stop or modify her training [12].

In the second trimester, the range of exercises is extended with movement exercises that make individual muscle groups more flexible, characterised by increased tension that limits joint mobility. Another group of exercises is aimed at strengthening those muscle groups that, when stretched due to pathophysiological changes, are characterised by a reduction in tension. The second trimester is suitable for introducing breathing exercises that engage the diaphragm, which is indirectly involved in labour. During pregnancy, the diaphragm rises by approx. 4 centimetres, thus reducing the total lung capacity by about 5% while the foetus's demand for oxygen increases [13]. The pelvic floor muscles play a significant role during childbirth. Another purpose of exercises in this trimester is the prevention of back pain, most often occurring in the lumbosacral section [14].

The third trimester is characterised by the most relaxed, low-intensity exercise proposal due to the maximum weight gain and mobility limitations. Relaxation techniques or stretching are often suggested to help a woman relax and calm down before labour. Some exercises require the support or assistance of an accompanying person [15].

Many biomechanical, metabolic, biochemical and psychophysical changes occur in the woman's body during pregnancy. In most pregnant women, these changes concern the musculoskeletal system, observed both in a static and dynamic position. When walking, the widening of the support plane and many other consequences can be observed. Examples include the works of Lee et al. [16] and Cakmak et al. [16, 17], in which the authors showed the relationship between changes in the musculoskeletal system and balance and stability disorders during pregnancy. This topic is crucial in the process of preventive measures to reduce the risk of adverse consequences of pregnancy.

Posturographic studies of pregnant women have shown changes in postural stability. Pregnancy has been shown to significantly reduce stability, primarily in the third but also in the second trimester, as manifested by an increase in path length and the centre of pressure (COP) area [18–21]. Deterioration of postural stability was observed to a greater extent in studies conducted with eyes closed [19, 20, 22, 23]. The centre of mass (COM) was shown to move more forward in pregnant women. However, no changes were observed in the lateral direction [24]. Increased postural sway was only significant in the anteroposterior (AP) direction [25]. This study suggests that the lack of change in the mediolateral (ML) direction is due to increased postural width, which improves lateral balance.

During pregnancy, the risk of falls increases significantly. Falls at some stage of pregnancy have been observed in up to 25% of study subjects [18, 26, 27]. Impaired body stability has often been cited as one of the reasons for the increased risk of falls. A positive correlation between the fall risk score and the anteroposterior stability index (APSI), the overall stability index (OSI) and the mediolateral stability index (MLSI) has been shown in women in the third trimester of pregnancy [19]. Takeda et al. [28] also noted that the posterior rectangular area of motion of the COP was larger in women who fell during pregnancy compared to women who did not experience a fall. Cakmak et al. [17], in a review of the literature covering the risk of falls in pregnancy and changes in postural balance, point to the significant impact of physical activity in reducing fall risk. They also point to the need for continued research to reduce falls by improving postural stability [17].

The study aimed to identify the relationship between regular physical training of pregnant women, carried out in the second and third trimesters of pregnancy, and the postural stability during the perinatal period: pregnancy and the postpartum period. Detailed analyses of the research results will make it possible to update and expand the knowledge on the legitimacy of physical training in women during their first physiological pregnancy.

Material and methods

Subject groups

64 women aged 25–35 applied for the research. They were divided into two groups according to their own choice. The study group (exercise group $N = 34$) consisted of women covered by the ‘Active in Pregnancy’ program, practising physical training three times a week during the second and third trimesters of pregnancy. The control group (non-exercise group $N = 30$) did not engage in physical activity of their own choice. During the project, 6 people resigned for personal reasons: 5 from the exercising group and 1 from the non-exercising group. Finally, 58 people completed the program: 29 in the study group and 29 in the control group. The loss rate for the entire group was 9.4%.

The research project was carried out at the Diagnostic and Research Laboratory of the Wroclaw University of Health and Sport Science. Measurement procedures were identical for both groups and took place during individual hour-long meetings. All tests were performed three times.

The deadlines were as follows:

– Examination 1 – turn of the 2nd trimester of pregnancy, i.e. 12 weeks of pregnancy (± 1 week);

– Examination 2 – third trimester of pregnancy – 2 weeks before the planned date of delivery;

– Examination 3 – postpartum period – 6 weeks after delivery.

To select the study group and prevent undesirable events, the following criteria were developed for inclusion in the study:

Inclusion criteria: the first, single and live intrauterine pregnancy confirmed in a medical examination, a certificate from the attending physician about the lack of contraindications to participate in aerobic training, planned physiological delivery, age range between 20 and 35, a woman practicing moderate physical activity before pregnancy, a woman expressing their voluntary consent to participate in the experiment.

Exclusion criteria: prenatally diagnosed foetal developmental defect, conditions resulting from spinal surgeries as well as abdominal and pelvic floor surgeries, conditions after pelvic fractures, mental disorders, diabetes, hypertension, women practising competitive sports before pregnancy.

After getting acquainted with the conditions of the research project, each woman decided at the first organisational meeting about participation in regular physical activities. A valid doctor’s certificate of no contraindications to physical exercise was presented by all patients from the exercise group. The voluntarily non-exercising group did not engage in additional, regular physical activity beyond their daily routine. Moderate activities, defined by the WHO as physical activity conducted with a subjective intensity of 5 out of 10 on a 2-point scale, were allowed. Conditions were not changed during the study. Apart from daily physical activity, women from the exercise group also performed exercises according to a training plan three times a week. During the program, there were occasional absences not exceeding 1–2 in the entire 12-week cycle.

The entire project was completed by 29 women in the study group and 29 women in the control group.

Training program protocol

The classes were conducted in the ‘Fitness Latte’ fitness club in Wrocław and local fitness clubs equipped with the necessary equipment. The training sessions were conducted by qualified instructors and trainers authorised to work with pregnant women. Exercise intensity was individually set at 60–70% HRmax.

The exercise program for each woman lasted 30 weeks during the second and third trimesters of pregnancy, and exercise was performed 3 times a week.

Each training session lasted 45–50 min and included 3 parts:

– warm-up – with elements of dance and yoga (10 min),

– main part – with fitness techniques, Pilates, yoga, aerobic exercises, resistance exercises (30 min),

– relaxation – with elements of stretching (5–10 min).

The positions used during the classes included standing, lying on the side, supported kneeling, sitting on a ball, sitting cross-legged and lying on the back. The number of repetitions of each exercise was 8–16 times and breaks between sets of exercises were 30 s. During the training, the most important principles of the training for pregnant women were observed. They included shorter exercises in the supine position due to the pressure of the uterus on the inferior vena cava, infrequent and gentle changes in the position of exercises, minimising the risk of stretching the rectus abdominis above the norm, proper breathing, and supplementing liquids [29].

Aerobic exercises of moderate intensity at the level of 60–70% of the maximum heart rate were used based on international guidelines [30]. The level of exercise intensity was set individually for each participant [31]. During the exercises, the heart rate of each woman was monitored using a heart rate monitor, i.e., a portable device in the form of a wristband.

Each participant in the study was individually instructed by the trainer to exercise at a moderate intensity. New, difficult exercises were gradually introduced, and loads were limited during resistance exercises. HR-monitoring wristbands were an additional safeguard to suggest and impose a safe set training pace.

Testing methods

Measurement of anthropometric features

The women's body weight was measured with an accuracy of 0.1 kg using a RADWAG WPT 100/200 medical scale with a height gauge. Once, in the first stage of the study, the body height was measured with an accuracy of 0.1 cm, from which the body mass index (BMI) was calculated.

Assessment of body posture stability

Body posture stability was assessed based on registering the resultant displacement of the centre of foot pressure (COP). A FreeMed Posture posturographic platform was used for this purpose. Stabilography is an objective assessment of the degree of deflection of the centre of pressure of the feet (COP) in a standing position, which in static conditions is a projection of the general centre of gravity of the body (centre of mass, COM) to the support plane [32]. The posturographic (stabilographic) examination is non-invasive, safe and suitable for all people who can maintain an upright body position. The examination does not require any preparation as the only condition is that the examined person can maintain an independent standing position. The orientation of points on the platform for positioning the bare feet provides additional help, facilitating adopting an appropriate physiological position or the so-called quiet position with the free arrangement of the upper limbs along the body.

COP displacements were measured in a standing position during three 30-second tests: eyes open (test 1), eyes closed (test 2) and feedback (test 3). During each 'eyes closed' test, the tested person was secured to eliminate the slightest risk of falling. The result of each test was recorded only after 4 s to eliminate spontaneous tilts as a result of taking the starting position.

Feedback test – posturographic measurement with visuo-motor feedback (conscious visual control) consisted of the observation and control by the tested person of the momentary point of her own COP mapped on the computer screen. The task of the examined person was to keep the point representing the COP in the given area throughout the test.

The platform registers displacements in the forward-backwards direction (sagittal plane – Y-axis) and the lateral direction (frontal plane – X-axis). The following parameters were analysed:

– radius – average radius of the COP deflections from the centre of the coordinate system [mm],

– area – size of the developed surface area [mm^2],

– length – average distance travelled by COP [mm],

– speed – average speed of COP movement in a complex motion, in the X and Y axis [mm/s],

– coordination – determined by the percentage of time of the entire test with maintaining the COP within the stationary, centrally placed square on the computer screen [%].

Assessment of back pain

Back pain was assessed using the Visual Analogue Scale (VAS), which is a tool that evaluates pain intensity. It is widely used and accepted to determine the intensity of pain [33–35].

Statistical analysis

The Shapiro–Wilk test was used to check the distribution of all quantitative variables. The normal distribution was confirmed for the variables describing the somatic features of the subjects. However, the normality of posturographic examination results was not confirmed. Descriptive statistics were calculated. Depending on the distribution, the arithmetic mean or median was used to measure the central tendency and the standard deviation (*SD*) or the interquartile range (IQR) as a measure of the dispersion. The significant differences between the groups were tested using Student's *T* test for independent samples, the Mann–Whitney *U* test, or the Chi-square test. The significant differences between the two groups and repeated measures were checked using Friedman's ANOVA and when the analysis of variance was statistically significant, using the Dunn Bonferroni-Holm post-hoc test. Additionally, to determine the quantity of the effect of differences between the examined groups, a corrected Cohen's *d* test was used. The effect size of the ANOVA was calculated by the Eta squared (η^2) and then transformed to the Cohen's *d* value [36]. The analysis was performed in Statistica 13.3 (TIBCO Software Inc. USA) and PQ Stat 1.8.2 (PQStat Software Poland) software, and the online statistical calculators available at the website http://www.psychometrica.de/effect_size (access date: 22.06.2023). The value of the coefficient $p < 0.05$ was assumed as the level of statistical significance.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Bioethics Committee of the Wroclaw University of Health and Sport Sciences, Poland (approval No.: 08/03/2018).

Informed consent

Informed consent was obtained from all individuals included in this study.

Results

Detailed characteristics of the study groups are presented in Table 1. The study groups did not differ statistically significantly regarding basic somatic features in all three examinations.

During pregnancy and the puerperium, a significant difference was observed in terms of back pain and its intensity in favour of the exercise group. The relationship between these parameters and regular physical activity has been demonstrated. The differences were statistically significant.

While assessing the stability of the body posture, the values of the radius, area and the area of deflection of the general centre of gravity as well as the length of the path and the speed of movement of the COP projection on the support plane, recorded in the test with the eyes open and closed, and during the control of the body position (feedback) were analysed (Tables 2–4). In addition, the value of the Romberg quotient was calculated, which is the ratio of the parameters obtained in tests carried out with the eyes open to the parameters obtained in tests carried out with the eyes closed. The coordination coefficient – the percentage time of the COP projection in the given field (square) during the biofeedback test (Tables 2–4) – was also determined.

The study conducted with open eyes and closed eyes showed no statistically significant differences between the measurements and the groups of subjects. However, in the measurements recorded with closed eyes, in the group of exercising women, the lowest values of stabilogram parameters (radius, area, length and speed) were observed in the last examination (postpartum) and the highest in examination 2 (in the third trimester

Table 1. Characteristics of somatic features and pain in both study groups

Groups' characteristics		Exercise group		Non-exercise group		T/Chi^2/U	Cohen's *d*
		mean	*SD*	mean	*SD*	*p*	
Body height (cm)		164.16	6.97	164.75	6.05	0.7324	0.09
BMI (kg/m^2)	examination 1	22.15	2.04	22.69	2.60	0.3839	0.23
	examination 2	25.07	2.52	26.01	3.04	0.2085	0.34
	examination 3	21.82	2.02	23.05	2.59	0.0514	0.54
Back pain N (%)	yes	79.30%		100%		0.0097*	0.72
Pain intensity VAS scale		3.96	2.33	5.72	2.17	0.0082*	0.64

T – Student's *t*-test, *U* – *U* Mann–Whitney's test, BMI – body mass index, VAS scale – Visual Analog Scale
* $p < 0.05$

Table 2. Stabilographic projection of the COP recorded with eyes open

Open eyes test	Exercise group						Non-exercise group						ANOVA p	Cohen's d
	examination 1		examination 2		examination 3		examination 1		examination 2		examination 3			
	median	IQR	median	IQR	median	IQR	median	IQR	median	IQR	median	IQR		
Radius (mm)	2.70	1.20	3.30	1.90	2.90	1.70	2.80	1.50	3.30	1.60	3.15	1.55	0.0912	0.845
Area (mm^2)	228.00	113.00	344.00	159.00	263.00	211.00	247.50	120.50	298.00	171.00	253.00	190.00	0.0715	0.883
Length (mm)	268.00	61.00	262.00	37.00	277.00	36.00	274.00	65.50	269.00	60.50	272.00	32.00	0.9855	0.158
Speed (mm/s)	8.40	1.95	8.20	1.20	8.65	1.10	8.55	2.00	8.40	1.85	8.50	1.00	0.9887	0.173

IQR – interquartile range

Table 3. Stabilographic projection of the COP recorded with eyes closed

Closed eyes test	Exercise group						Non-exercise group						ANOVA p	Cohen's d
	examination 1		examination 2		examination 3		examination 1		examination 2		examination 3			
	median	IQR	median	IQR	median	IQR	median	IQR	median	IQR	median	IQR		
Radius (mm)	3.25	0.95	3.50	1.45	3.00	1.40	3.40	1.60	3.70	1.90	3.40	1.70	0.1692	0.742
Area (mm^2)	303.00	91.50	383.00	213.00	251.00	200.00	309.00	253.00	327.00	194.00	362.00	247.00	0.2282	0.686
Length (mm)	304.00	53.00	338.00	147.00	295.00	126.00	313.00	103.50	318.00	97.00	317.00	102.00	0.5210	0.492
Speed (mm/s)	9.50	1.70	10.60	4.60	9.25	3.95	9.75	3.25	9.90	3.00	9.90	3.20	0.5343	0.485
Romberg	1.22	1.22	1.21	0.77	1.15	0.56	1.41	0.54	1.19	0.69	1.14	0.45	0.2696	0.653

IQR – interquartile range

Table 4. Stabilographic projection of the COP recorded in feedback conditions

Feed-back test	Exercise group						Non-exercise group						ANOVA p	Cohen's d
	examination 1		examination 2		examination 3		examination 1		examination 2		examination 3			
	median	IQR	median	IQR	median	IQR	median	IQR	median	IQR	median	IQR		
Radius (mm)	3.05	1.70	3.20	0.90	2.30	0.80	3.10	1.60	3.00	1.40	2.80	0.90	0.0005*	1.56
Area (mm^2)	392.00	270.00	360.00	266.00	198.00	107.00	338.00	204.00	289.00	178.00	260.00	116.50	< 0.0001*	2.18
Length (mm)	392.00	113.00	338.00	128.00	275.00	64.00	364.00	113.00	317.00	72.00	295.00	68.00	< 0.0001*	2.07
Speed (mm/s)	12.30	3.50	10.60	4.00	8.60	2.00	11.40	3.50	9.90	2.20	9.20	2.10	< 0.0001*	2.06
Coordi-nation (%)	62.90	28.90	59.50	18.30	79.00	17.20	58.10	30.60	66.90	22.80	67.90	23.20	0.0024*	1.35

IQR – interquartile range, * $p < 0.05$

of pregnancy). In the non-exercising group, the same study showed the lowest stabilogram values obtained in examination 1. It was also observed that in the exercise group in the last examination, lower values were recorded compared to the non-exercise group, except for the Romberg test (Table 3). The feedback test showed that the lowest values of the radius, area, length and speed in both groups were obtained in measurement 3 (postpartum).

In examination 3, there was also a difference in the values obtained by the two groups. The stabilogram values characterising the exercise group were lower than in the non-exercise group (Table 4).

Table 5. Comparison of the study group and control group in three examinations

Exercise group vs. non-exercise group		Examination 1 p	Examination 2 p	Examination 3 p
Feedback test	radius (mm)	1.00	1.00	0.2768
	area (mm^2)	1.00	0.6424	0.7496
	length (mm)	1.00	0.5724	1.00
	speed (mm/s)	1.00	0.5636	1.00
	coordination (%)	1.00	1.00	0.8978

p – coefficient p of the Dunn Bonferroni-Holm post hoc test

Table 6. Comparisons between measurements in both groups

Examination		Exercise group p			Non-exercise group p		
		1 vs 2	1 vs 3	2 vs 3	1 vs 2	1 vs 3	2 vs 3
Feedback test	radius (mm)	1.00	0.0019*	0.0034*	1.00	1.00	1.00
	area (mm^2)	1.00	0.0003*	0.0004*	0.6423	0.0615	1.00
	length (mm)	1.00	0.0001*	0.0056*	0.6208	0.1032	1.00
	speed (mm/s)	1.00	0.0001*	0.0053*	0.6431	0.1048	0.5557
	coordination (%)	1.00	0.0534	0.0034*	1.00	0.8666	0.0616

p – coefficient p of the Dunn Bonferroni-Holm post hoc test, * $p < 0.05$

For variables whose ANOVA showed statistical significance (feedback test), a post hoc analysis was performed to check which factors were significantly different. None of the three measurements showed significant differences between the exercising and non-exercising groups (Table 5).

In the exercise group, the feedback test showed statistically significant differences between measurements 1 and 3 and between 2 and 3. In the measurement made postpartum, significantly lower/better stabilogram values were recorded compared to tests performed during pregnancy.

Statistically significant differences were not confirmed for the non-exercising group (Table 6).

Discussion

Analysis of body posture stability is an important element of research conducted among pregnant women. As a result of studies by Vardi et al. [37], changes in postural stability, confirmed by a greater centre of gravity displacement in the anterior-posterior direction on a posturographic platform in static conditions, were observed in women in the third trimester of pregnancy compared to non-pregnant women. The detected changes persisted for several months after the end of the postpartum period. A similar tendency was also observed in the dynamic mode, where as a result of gait modification, a significant extension of the support plane was noted [37]. Different results are presented in the work of Krkeljas [39]. According to these results, the kinematics of gait do not differ in subsequent stages of pregnancy, and anterior-posterior postural sway does not occur during gait. However, a relationship between the width of the step during walking and the lateral tilt of the pelvis was demonstrated. The study's results confirmed that weight gain significantly affected the change in body posture and gait. According to the researcher, exercises during pregnancy should be aimed at strengthening the postural muscles and stabilising the pelvis. The analysis in our study confirms the relationship between the initial BMI value and the area determined by the COP trace.

Carvalho et al. [40] presented studies in which they confirm that low back pain is the most common musculoskeletal ailment during pregnancy and is responsible for many adverse effects on pregnant women's static and dynamic balance. Based on the research results, the authors suggest taking preventive measures, training and rehabilitation programs to prevent the ailments mentioned above. Thus, a common direction of discussion was found in the analysis of our studies, as they indicate a relationship between back pain and a lack of regular physical activity during pregnancy. Our research showed less frequent back pain and its lower intensity in the group of pregnant women participating in systematic exercises.

Back pain results from natural pathophysiological changes in the woman's body during pregnancy. The etiology and pathomechanism of progressing pregnancy changes are discussed in detail in the works of Polish researchers. The changes concern mainly the myofascial and osteoarticular systems: pelvic anteversion, deepening of the lumbar lordosis and joint contractures within the shoulder and hip joints, stretching or compression of muscles and other structures, relaxation of the cartilage tissue due to the increase in the level of the hormone relaxin, hypertrophy of the uterus, displacement of the uterine bones relative to each other, upward displacement of the diaphragm with compensation within the lungs, lowering of the pelvic floor muscles, and compression of the bladder and associated structures. The reason for these changes is primarily the maturation and enlargement of the foetus, which results in an increase in the mother's body weight of about 12 kg under normal conditions, of which only 38% is the actual weight of the foetus, while 62% is the placenta, amniotic fluid, blood and other fluids. As a result of the accumulation and retention of water in the pregnant woman's body and the increased production of relaxin, intervertebral cartilage, symphysis pubis cartilage and the sacroiliac joints are loosened. Loosening and stretching of the ligaments, cartilage joints, and other structures causes changes in body posture and problems with maintaining it, and consequently, chronic pain symptoms, mainly in the lumbosacral spine [41].

In another article, researchers describe the effectiveness of rehabilitation intervention programs for reducing low back pain and improving the postural stability of pregnant women. In one group of subjects, stabilisation exercises were used and in the other group, stretching exercises. Both interventions were successful [42]. In our study, the impact of training activity on the postural parameters of the body of pregnant women was assessed. In future research projects, it is worth considering comparing the impact of training and rehabilitation programs on the population of pregnant women.

In our study, no statistically significant differences in postural stability parameters were found between the group undertaking regular physical activity during pregnancy and the group that was not exercising. An increase in the radius of anterior-posterior deflections before delivery, characteristic of changes generated by pregnancy, and a decrease in these deflections after the puerperium were observed in both groups with a value equal to almost zero in the study group. However, there were statistically significant differences in the results of the analysed coordination parameter in both groups of women. Unlike the control group, the group performing regular physical training was characterised by better coordination ability throughout the perinatal period, even at the stage of advanced pregnancy.

Paying attention to the proven relationship between regular training and the coordination parameter seems important because it may support the assumption of the need for regular preventive activity of pregnant women to improve the quality of functioning in everyday life and to prevent falls during pregnancy. Similar conclusions were made based on research by Danna-Dos-Santos et al. [43]. According to the researchers, problems resulting from balance and coordination disorders in pregnant women are already observed in the early stages of pregnancy. Posturographic platforms seem to be the optimal measurement tool.

In our study, relations between imbalance in the form of anteroposterior leaning and physical training were recognised. Significant differences were observed, especially between groups, between measurements taken before and after delivery. In the exercise group, the analysed parameters normalised more rapidly. Opala-Berdzik et al. [44], based on physical activity questionnaires, divided the observed women into two groups: self-exercising and non-exercising. The results of the static postural stability measurements showed no significant differences in the postural stability of the two groups of subjects either during pregnancy or postpartum [44]. However, they showed a significant increase in the amplitude of anterior-posterior leaning and a significant increase in the base of support width of women in the third trimester of pregnancy compared to women in the second and sixth months postpartum [23].

Our work was analysed in terms of strengths and weaknesses to optimise the plan and organise research on similar issues. The strong point of the work is the presence of two researched groups, active and inactive, differing in their involvement in regular physical activity. Both groups were tested according to the same protocol, and the results were compared. The tests were performed three times, which allowed us to track the pace and dynamics of changes throughout pregnancy and after birth. A posturographic platform was used for the research, which is conducive to objectification, not based only on subjective survey methods. Studies of the pregnant women's actual functional values made it possible to find relationships between many body functions and physical activity. Optimising the physical activity of pregnant women can contribute to a safe passage of pregnancy.

We did not avoid certain limitations in our study. The weakness of the research is the size of the groups, with too few respondents, comprising only 29 women in each group. The reason seems to be the long, multistage research period (about 40 weeks) during what can be an unstable life period for pregnant women. Another limitation is the fact that the study did not involve a random sample, but a so-called targeted sample. The study was attended by women who independently chose the study group or the control group. The physical activity of the participants before pregnancy was also not analysed in detail.

Conclusions

The assessment of body posture stability parameters showed significant differences only in terms of body coordination in favour of the active group of women. In the exercise group, the postpartum measurement showed statistically significantly lower values of the posturography parameters, indicating better postural stability compared to measurements taken during pregnancy.

The best coordination result was also observed in the measurements performed postpartum. There were no significant differences between measurements taken during pregnancy.

In the group of non-exercising women, no significant differences were observed between measurements taken during pregnancy and the measurement performed postpartum.

The other analysed parameters of postural stability (eyes-open and eyes-closed tests) in both groups showed similar characteristic changes generated by pregnancy.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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