Maziarz Agata, Ogonowski Jarosław, Szylińska Aleksandra, Wiatrak Adrian, Turoń-Skrzypińska Agnieszka, Rotter Iwona. An assessment of the impact of physical activity undertaken by patients with gestational diabetes mellitus on neonatal birth weight. Journal of Education, Health and Sport. 2018;8(12):169-183. eISNN 2391-8306. DOI http://dx.doi.org/10.5281/zenodo.2064733
http://ojs.ukw.edu.pl/index.php/johs/article/view/6358

The journal has had 7 points in Ministry of Science and Higher Education parametric evaluation. Part B item 1223 (26/01/2017).
1223 Journal of Education, Health and Sport eISSN 2391-8306 7

The authors declare that there is no conflict of interests regarding the publication of this paper.

Received: 18.11.2018. Revised: 25.11.2018. Accepted: 08.12.2018.

An assessment of the impact of physical activity undertaken by patients with gestational diabetes mellitus on neonatal birth weight

Agata Maziarz[1], Jarosław Ogonowski[2], Aleksandra Szylińska[1], Adrian Wiatrak[1], Agnieszka Turoń-Skrzypińska[1], Iwona Rotter[1]

1. Department of Medical Rehabilitation and Clinical Physiotherapy, Pomeranian Medical University in Szczecin, Poland
2. Autonomous Laboratory for Diseases of Civilization and Obesity Treatment, Pomeranian Medical University in Szczecin, Poland

Abstract
Background
Recent years have seen a growing interest in the physical activity of pregnant patients and its effects on obstetric outcomes. Apart from its positive influence on healthy pregnant patients, moderate physical effort also plays an important role in therapeutic procedures in women diagnosed with gestational diabetes mellitus. The aim of this paper was to assess the link between daily physical activity of patients diagnosed with gestational diabetes mellitus and neonatal birth weight.
Material, patients and methods-
The study group included 100 patients with gestational diabetes mellitus (GDM) between 26 and 32 weeks' gestation. Their physical activity was assessed using the International Physical Activity Questionnaire (IPAQ), the Pregnancy Physical Activity Questionnaire (PPAQ) and a pedometer.
Results
No significant correlation between neonatal birth weight and the parameters describing the type and intensity of physical activity was shown. Neonatal birth weight correlated positively with pregravid BMI of the pregnant patient. A negative correlation was identified between gestational weight gain and pregravid BMI.
Conclusion
There was no relationship between daily physical activity during pregnancies complicated by diabetes mellitus and neonatal birth weight. Maternal pregravid weight was found to be an important parameter affecting the infant's weight.

Key words: birth weight, physical activity, gestational diabetes mellitus

Introduction

Physical activity has a positive effect on healthy pregnant patients, and plays an important role in therapeutic procedures in women diagnosed with GDM. Two types of diabetes mellitus that may occur during pregnancy are distinguished: the first one is pre-gestational diabetes mellitus (PGDM), where a woman already diagnosed with diabetes mellitus – regardless of its type – becomes pregnant, or where hyperglycemia is first diagnosed during pregnancy. The second one is gestational diabetes mellitus (GDM), which is the most prevalent metabolic disorder present during pregnancy. GDM is defined as glucose intolerance of varying severity. It is usually diagnosed at 24-28 weeks' gestation on the basis of oral glucose tolerance test results [1].

Of all the neonatal anthropometric parameters, birth weight appears to have the most significant effect on the child's future health. Of particular importance is excessive birth weight equaling or exceeding 4,000 g, which is defined as macrosomia. This corresponds to the 90th percentile at 40 weeks' gestation according to standard growth charts. More precisely, the 90th percentile or higher at any time of the pregnancy denotes excessive fetal weight in relation to gestational age (or LGA for 'large for gestational age'). Studies show that macrosomia is an important risk factor for obesity, diabetes mellitus type 2, or metabolic syndrome in school age, adolescence or adult life [2-5]. A higher risk of macrosomia in the child is related to many factors, such as maternal obesity, pathologic maternal weight gains during pregnancy, hyperglycemia during pregnancy, higher age of the pregnant patient, and genetic and ethnic predispositions. What is more, the mother's macrosomia may be another factor resulting in a larger neonatal birth weight [6-13]. While the mother's age, the number of children born, previous births of macrosomic neonates, genetic load, descent, or maternal birth weight are beyond any control and cannot be changed, the remaining features such as the woman's body weight, gestational weight gain and blood sugar level can be modified by intervention [14]. Introducing an appropriate nutritional model and physical exercises in women diagnosed with gestational diabetes mellitus has been observed to have a positive effect on the final obstetric outcome. In one study, there were differences between the group of women subjected to intervention and the control group, which were expressed in lower neonatal birth weights. Its authors also noted that irrespective of whether diabetes mellitus was controlled or not, the presence of obesity reduced the therapeutic effectiveness of the applied interventions, thus having a negative impact on the course of the pregnancy and the final outcome [15]. Moreover, in another study, after processing the results of three meta-analyses it was found that the difference in neonatal birth weights between women who exercised during pregnancy and the control group was minimal or non-existent. Nevertheless, the women that continued intensive exercises into the third trimester delivered more babies weighing 200-400 g less than the control group, and no increased risk of intrauterine growth restriction was observed [16].

Objectives

To assess the link between daily physical activity undertaken by pregnant women with diabetes mellitus and neonatal birth weight.

Material, patients and methods

The study carried out between July 2015 and March 2016 at the Diabetes Outpatient Clinic of the Autonomous Public Combined Provincial Hospital of Szczecin included 100 women between 26 and 32 weeks' gestation demonstrating hyperglycemia first diagnosed during the pregnancy. Patients with multiple pregnancies, pre-gestational diabetes mellitus, using hyperglycemic drugs or having other severe ailments that develop during pregnancy were excluded from the study. The study received a positive review from the Institutional Review Board Review of the Pomeranian Medical University of Szczecin (KB-0012/88/15).

The data gathering process was divided into three stages – a questionnaire-based interview, pedometer measurement, and a phone follow-up after labor. Details about their body weight, height and family and obstetric history of conditions, as well as biochemical data – such as OGGT and HbA1c results – were obtained. Their physical activity was assessed using two questionnaires – the International Physical Activity Questionnaire (IPAQ) and the Pregnancy Physical Activity Questionnaire (PPAQ) – and a pedometer that the patients wore for 3 days. At approximately 1 to 3 months after labor they were asked to provide information about the week and type of labor, the method by which their diabetes mellitus had been treated, neonatal birth weight and length, and the infant's sex.

Also, their BMI (Body Mass Index) was calculated. The BMI is a simple indicator of the body weight to height ratio, commonly used for classifying underweight, overweight and obesity in adults. The WHO defines it as a person's weight in kilograms divided by the square of the person's height in meters (kg/m^2).

Using the body mass index, the patients were divided into three groups: one of women with normal weight (the standard weight was between 18.5 and 24.9 kg/m^2), one of overweight patients (weighing between 25 and 29.9 kg/m^2) and one of obese patients (>30 kg/m^2). The BMI was calculated by dividing pregravid weight by the square of their height in meters (kg/m^2).

Statistical analysis

The gathered results were analyzed using the licensed Statistics 12 software (StatSoft, Inc. Tulsa, OK, USA). The averages, standard deviations, interquartile ranges and percentage shares were calculated for the individual parameters. Further on, the Student's t-test or the Mann–Whitney U test were performed for independent samples, and matrices of correlation between two lists of variables were developed. The $p \leq 0.05$ significance level was assumed.

Results

Out of the 100 studied patients, 3 were underweight, 51 demonstrated normal body weight prior to pregnancy, 25 were overweight, and 21 were obese. The underweight patients were excluded from any further analysis. Table 1 contains basic details of the patients, divided by their pregravid BMI.

Table 1. Comparison of basic characteristics of the studied women.

	standard (n=51)	**overweight (n=25)**	**obesity (n=21)**	**p**
	Average ± standard deviation			
Age (in years)	29.90 ± 4.73	29.00 ± 5.00	29.48 ± 5.44	NS
Pregravid BMI (kg/m^2)	22.22 ± 1.73	27.11 ± 1.27	35.14 ± 4.70	**<0.001**
Pregravid weight (kg)	61.37 ± 6.49	75.43 ± 7.50	97.33 ± 14.49	**<0.001**
Height (m)	1.66 ± 0.06	1.67 ± 0.07	1.66 ± 0.04	NS
Gestational weight gain (kg)	10.76 ± 5.45	7.87 ± 5.31	2.97 ± 9.17	**<0.001**
Week of labor	38.70 ± 1.91	39.00 ± 1.00	39.00 ± 1.00	NS
Type of labor (number of studied patients and %) natural labor: C-section	28:23 55%:45%	8:17 32%:68%	7:14 33.3%:66.7%	NS
Maternal birth weight (g)	3170.00 ± 656.60	3248.00 ± 561.00	3181.00 ± 555.00	NS
Neonatal birth weight (g)	3208.78 ± 456.97	3451.00 ± 492.00	3368.00 ± 409.00	**0.038**
No. of children (number and %) <2500 g: 2500-4000 g: >4000 g	2:48:1 3.9%:94.1%:2%	1:21:3 4%:84%:12%	0:20:1 0:95%:5%	**0.008**
Length of infant (cm)	53.84 ± 3.41	56.00 ± 4.00	54.00 ± 0.00	NS
75 g OGTT				
Glucose level at 0' (mg/dl)	93.37 ± 9.63	90.98 ± 10.98	92.92 ± 8.12	NS
Glucose level at 60' (mg/dl)	168.1 ± 33.27	158.80 ± 42.11	166.67 ± 33.81	NS
Glucose level at 120' (mg/dl)	143.82 ± 30.48	141.25 ± 35.46	137.31 ± 24.21	NS
HbA1c (%)	5.06 ± 0.28	4.86 ± 1.15	5.31 ± 0.26	**0.001**
GDM1: GDM2 (number and %)	32:19 62.7%:37.3%	12:13 48%:52%	8:13 38%:62%	NS

BMI – Body Mass Index
n – number of the group's members
p – significance level

Differences between body weight gains were observed, and they were statistically significant between all the groups. The higher the BMI, the lower was the weight gain. Moreover, women with normal body weights had smaller babies compared to overweight patients. Obese patient had higher glycated hemoglobin levels and a larger share of macrosomic babies than those with a normal weight. The remaining parameters, such as maternal birth weight, glucose tolerance test results, GDM1 and GDM2 frequency, and the week and type of labor, did not differ significantly.

Table 2 shows the measurements results for physical activity undertaken by the studied pregnant women.

Table 2. Physical activity parameters of pregnant women.

BMI (kg/m^2)	18.5-24.9	25-29.9	>30	p
PPAQ MET-hrs/wk - average (standard deviation)				
Sum	175.19 (61.79)	176.93 (68.16)	176.72 (122.4-227.8)	NS
Moderate act. % of all	38.84 (31.35) 22.17%	46.40 (43.09) 26.22%	36.93 (38.22) 20.9%	NS
Intensive act. % of all	0.00 (0.00) 0%	0.00 (0.00) 0%	0.00 (0.00) 0%	NS
IPAQ MET-hrs/wk - average (standard deviation)				
Sum	61.66 (58.05)	61.94 (59.07)	40.79 (38.98)	NS
Moderate act.	27.65 (37.22)	17.40 (20.56)	26.71 (30.23)	NS
Intensive act.	8.63 (28.62)	9.60 (24.92)	8.20 (23.55)	NS
PPAQ MET- hrs/wk - average (standard deviation)				
Sedentary act. % of all	44.71 (20.11) 25.52%	39.49 (16.50) 22.32%	50.12 (26.18) 28.36%	NS
Light act. % of all	89.85 (36.12) 51.29%	90.52 (38.70) 51.16%	89.15 (40.18) 50.45%	NS
Housework % of all	92.39 (50.86) 52.74%	95.44 (69.12) 53.95%	95.46 (69.87) 54%	NS
Professional work % of all	2.87 (12.48) 1.64%	7.22 (25.04) 4.1%	3.87 (14.83) 2.19%	NS
Sports % of all	11.35 (7.36) 6.48%	8.96 (5.21) 5.1%	5.87 (3.35) 3.32%	**0,024**
IPAQ - average (standard deviation)				
Sitting hrs/wk	31.01 (13.75)	24.78 (9.79)	31.42 (11.34)	**0,039**
Walking MET-hrs/wk	25.38 (22.58)	34.94 (32.98)	10.87 (10.58)	**0,003**
General activity score (no. and %) low: average: high:	9:19:23 17.6%:37.3%:45.1%	2:11:12 8%:44%:48%	7:8:6 33.3%:38.1%:28.6%	**0,042**
Pedometer steps/day – median (standard deviation)*				
Day 1	5936.46 (2978.34)	7789.00 (5705)	5122.00 (3086.00)	NS
Day 2	5771.85 (2388.16)	6971.00 (4848)	6074.00 (2637.00)	NS
Day 3 (holiday)	5252.28 (2388.16)	5008.00 (3178)	5410.00 (3132.00)	NS
Average steps	5616.71 (2340.86)	6516.00 (3178)	5535.00 (2582.00)	NS
General activity score (no. and %) sedentary: low: average: active: high:	23:16:6:3:0 47.9%:33.3%:12.5%:6.3 %:0	9:8:4:1:1 39%:34.8%:17.4%:4.4 %:4.4%	9:5:4:1:0 47.4%:26.3%:21%:5.3 %:0	NS

* for the pedometer: standard n=48, overweight n=23, obesity n=19

BMI – Body Mass Index, IPAQ – International Physical Activity Questionnaire, MET-hrs/wk – MET units expressed in hours per week, p – significance level, PPAQ – Pregnancy Physical Activity Questionnaire

As for the differences between women demonstrating normal weights and those with overweight, the only significant one was the amount of time they spent sitting during the day – this value was higher for the normal-weight patients than for the overweight women.

The differences between the overweight patients and the obese ones were as follows: women with higher BMIs spent more time sitting during the day, walked less, and their PPAQ showed smaller shares of exercises. What is more, differences in respect of the general activity score in the IPAQ were observed to be in favor of the lower BMI patients – their scores were higher.

To compare the results for the normal-weight group with those for the obese group, differences with regard to the time spent strolling and exercising were noted, with the slimmer patients demonstrating a higher share of such activity.

All the studied women were in the same period of pregnancy, namely between 26 and 32 weeks' gestation. The data obtained indicated that all the groups demonstrated similar activity as measured using the pedometer. The numbers of steps taken did not vary much between them depending on their original body weight. Also, no discrepancy was observed in the numbers of steps taken on working days and holidays.

The patients were also grouped by the levels of physical activity according to the general IPAQ score. Differences in obstetric outcomes were studied in relation to the patients' physical activity, but no significant dissimilarities were shown to exist between the particular groups (Table 3).

Table 3. The level of physical activity in relation to the obstetric outcomes.

	Average ± standard deviation			**p**
	low activity level	average activity level	high activity level	
number	19	39	42	NS
BMI	27.47 ± 8.13	26.15 ± 5.54	25.24 ± 4.76	NS
Obstetric outcomes				
week of labor	39 ± 1.5	38.5 ± 2.4	39 ± 1.2	NS
gestational weight gain (kg)	7.5 ± 6.8	7.3 ± 7	9.8 ± 7	NS
neonatal birth weight (g)	3213 ± 381	3224 ± 574	3370 ± 442	NS
Infant length (cm)	54.6 ± 2.3	53.5 ± 3.9	54.8 ± 3.3	NS
Type of labor (no. and %) nb: cs	8: 11 42.1%: 57.9%	18: 21 46.1%: 53.9%	19: 23 45.2%: 54.8%	NS

BMI – Body Mass Index, cs – C-section, nb – natural birth

The next stage of the analysis involved searching for any correlations between selected parameters.

No link was identified between the patients' physical activity and neonatal birth weight. The parameters compared were: the average number of steps, the average number of hours spent sitting during the week (IPAQ), walking in terms of MET-hrs/wk (IPAQ), the total number of MET-hrs/wk, and sporting activity using the PPAQ.

An attempt was undertaken to assess the correlation between the women's pregravid BMI and their levels of physical activity, as well as biochemical and obstetric parameters.

It turned out that there was a substantial negative correlation between the original body weight of the women and their weight gains during pregnancy. The higher weight of the given patient the lower was her weight gain. This correlation is shown in Figure 1.

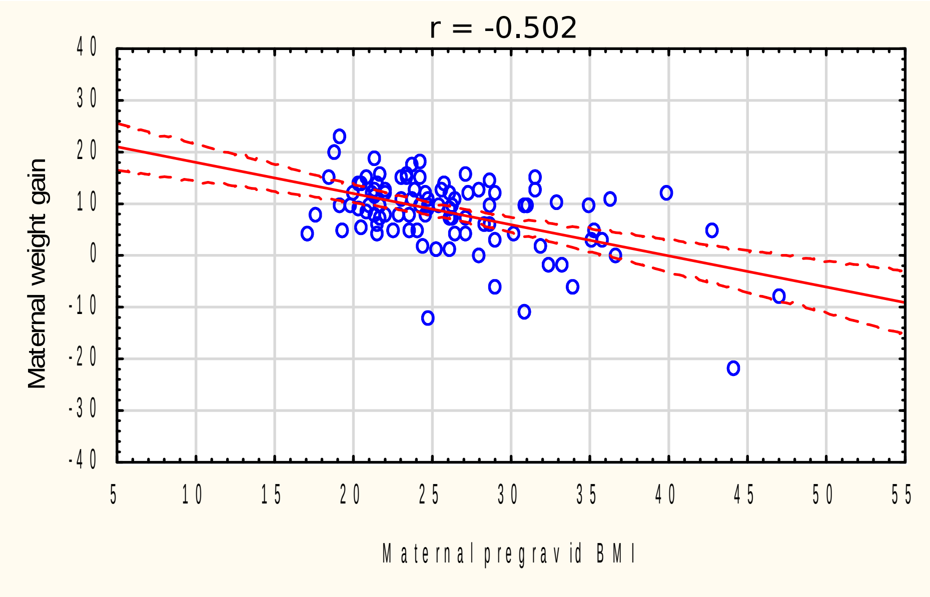

Fig. 1. Diagram of distribution – the correlation between maternal pregravid BMI and total weight gain during pregnancy.

Moreover, it was shown that body weight correlated positively with the glycated hemoglobin level (Figure 2.) and neonatal birth weight (Figure 3.). The higher the BMI, the higher was the patient’s HbA1c and neonatal birth weight.

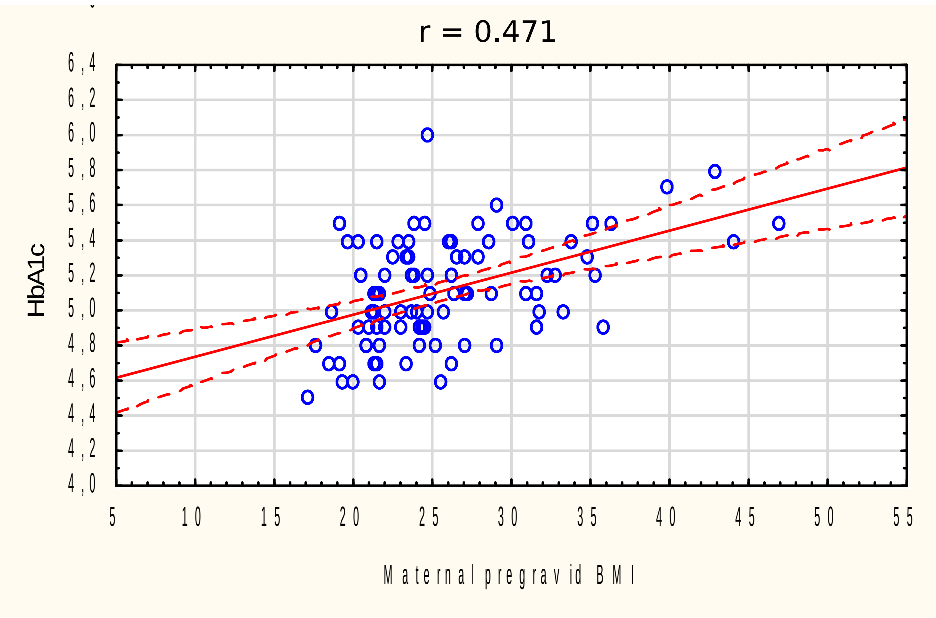

Fig. 2. Diagram of distribution – the correlation between maternal pregravid BMI and HbA1c.

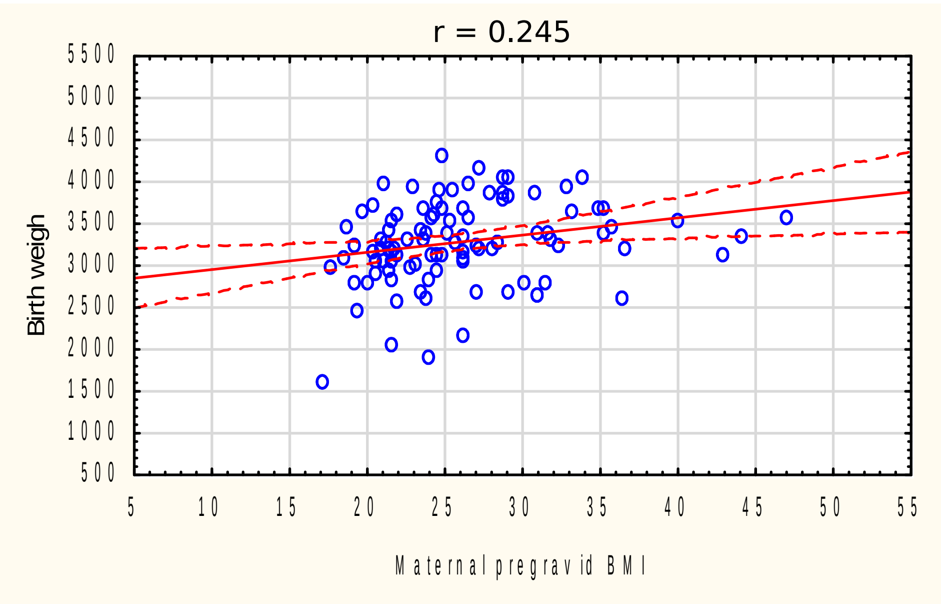

Fig. 3. Diagram of distribution – the correlation between maternal pregravid BMI and neonatal birth gain.

A correlation was found between pregravid BMI and only one parameter describing physical activity – the amount of time spent walking/strolling derived from the IPAQ. The higher their pregravid BMI, the less the women walked during pregnancy (Figure 4.).

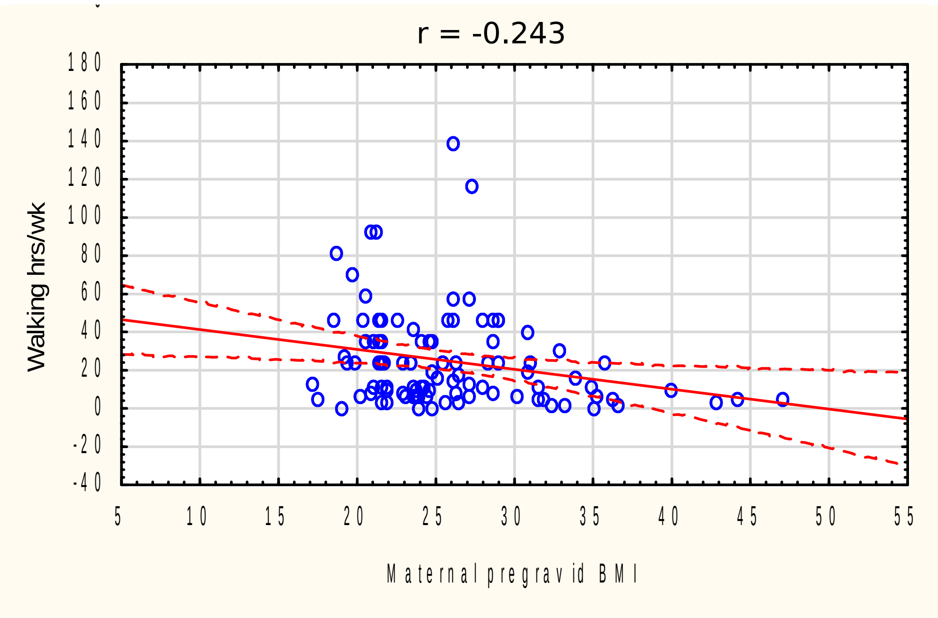

Fig. 4. Diagram of distribution – the correlation between maternal pregravid BMI and the amount of time spent walking per week.

Discussion

The 2015 ACOG guidelines on physical activity and exercise during pregnancy and the postpartum period indicate that there is no relationship between physical activity and obstetric complications, while such activity brings about numerous benefits [16].

An Australian team's research identified no significant correlation between the length and frequency of vigorous physical effort and average neonatal birth weight in the women studied. They only considered vigorous efforts undertaken by pregnant women who performed recreational physical exercises on a daily basis [17]. Therefore, the methodology used in that research differed from the one used in our study, where patients were asked to make a subjective assessment of their own activity, no heart rate could be measured, and their activity was calculated using a pedometer. Thanks to the methods adopted here, we were able to monitor not only their recreational activity, but also any activity undertaken during the day. The PPAQ allowed us to monitor not only recreational, but also domestic and professional activity.

Barakt et al. noted that light-intensity resistance exercises and toning exercises performed in the second and third trimesters by women who had earlier led a sedentary lifestyle, had no effect on neonatal birth weight [18]. They did not study the patients' natural activity, but rather a specific intervention was implemented, the results of which – similarly to our research – showed no correlation between physical activity (even if intensified, as in the study of Barakt et al.) and neonatal birth weight. Nevertheless, it was also observed that the women's body weight prior to pregnancy in the non-practicing group was positively and significantly correlated with the size of their babies, whereas no such link was identified for the practicing patients' group. A similar correlation was found in our study, where it was shown that pregravid BMI was an important factor affecting the size of the neonate. This was confirmed by another paper in which the influence of obesity and diabetes mellitus on the development of macrosomia was studied. It was shown that pregravid obesity was considerably linked to the risk of delivering an LGA baby. Moreover, the effects of existing diabetes mellitus on the risk of LGA were the largest in women who were originally obese [19]. In our study it was determined that obese patients delivered macrosomic babies more often than patients with lower body weights did, which was in agreement with the results of the paper quoted above. Moreover, the BMI >30 kg/m^2 group had a higher glycated hemoglobin level, which in itself could be a risk factor for a larger neonatal birth weight.

In another study including a control group, the effects of exercises performed to music (aerobics) on newborn's birth size were examined. As in the previously discussed study, the participants were women who had not been physically active prior to pregnancy. The study demonstrated that the undertaken activity did not impact the newborn's size. Hence, it was concluded that exercising appeared to be safe both for the pregnant patients and their children. However, the effects of maternal body weight on the obstetric outcome were not examined [20].

Other researchers studied the effects of physical activity and the share of resting activities on the risk of macrosomia. It was noted that women who were anticipated to deliver children of larger weights demonstrated a tendency to reduce their activity in the third trimester of pregnancy. It was suggested that the share of resting activities (or a change to a sedentary lifestyle) in the final period of gestation might potentially result in increased neonatal birth weights [21]. In our research, only the patients' activity at the turn of the second and third trimesters was examined. Therefore, it was impossible to monitor any changes in the women's patterns of activity throughout their pregnancies, or how such changes could have affected the final outcomes.

Melzer et al. studied how the recommended physical activity levels during pregnancy affected obstetric outcomes. Their study subjects were late in their pregnancies (35-41 weeks). A specialist measurement device in the form of a sensor was used, which the participants carried with them for 5 consecutive days without changing their lifestyle. After the results were analyzed it was found that the more active women spent more time doing medium-intensity activities than the inactive women did, but no differences were observed in respect of the amount of high-intensity activities. Moreover, no differences were identified between the groups of active and inactive patients with regard to neonatal birth weight [22]. Similar links were determined in our own study, where the highest-intensity physical activities accounted for a very small share of all the activities, which was a common phenomenon for all the patients studied, while the effects of physical activity on neonatal birth weight were statistically insignificant. Also, the influence of maternal weight gain during pregnancy on neonatal birth weight was studied. It was shown that patients with lower pregravid BMIs and lower weight gains had children with smaller weights than women with higher BMIs (>25 kg/m^2) and higher weight gains (>16 kg). The children of women with the highest BMIs and those who gained the most weight had the largest birth weights. Women with normal BMIs gained the most weight, while patients with a BMI >29 kg/m^2 gained the least. It was found that a considerable maternal weight gain during pregnancy resulted in a higher neonatal birth weight [23]. Those results were in agreement with the results of this paper. Higher BMI patients demonstrated lower weight gains, which might have had some impact on achieving normal obstetric outcomes regardless of their original BMIs.

In the DALI research, an intervention was performed among obese pregnant patients before 20 weeks' gestation, which consisted in introducing a healthy diet and/or physical activity. It was shown that the diet group demonstrated a lower weight gain in comparison to the group where only physical activity was applied. Hence, it appears that a well-balanced diet may be the main factor affecting the pregnant patients' weight gain [24]. It should be remembered that our study only included patients already diagnosed with GDM. Therefore, they had already been instructed by the therapeutic team on the appropriate diet to be observed, which was an important part of their treatment. In treating diabetes mellitus, appropriate nutrition plays a crucial role. Not only does it help maintain the correct blood glucose level, but also – by preserving the energy balance – allows for harmonious and normal weight gains [25]. As the aforementioned studies have shown, this last factor may have a significant impact on infant sizes.

Few of the available studies have been carried out exclusively on women with GDM. In assessing the impact of pregnant patients' physical activity on infant birth weights, not only the type of activity and the period of gestation in which the measurement are taken, but also – in the first place – maternal pregravid weight and postpartum weight (weight gain) should be taken into account. Another important element is whether or not the studied parameters have been modified – whether an intervention has been performed in order to increase the intensity of the patients' efforts, or whether the assessment is based on the patients' daily and natural physical activities, as was the case in our study.

Conclusion

Natural physical activity during GDM pregnancies does not affect neonatal birth weight. Infant birth weight is more affected by pregravid BMI of the mother than the physical activity she undertakes during pregnancy as expressed in MET-hrs/wk or the number of steps taken per day. Thanks to an appropriate treatment – mostly a diet – most of our patients were able to achieve correct obstetric outcomes. This was probably linked to maintaining blood sugar levels within the norm, and to maintaining proper weight gains.

References

1. World Health Organization (WHO) (2014). Diagnostic criteria and classification of hyperglycaemia first detected in pregnancy. Diabetes Res Clin Pract, 103(3): 341-63.
2. Wallace S, McEwan A (2007). Fetal macrosomia. Obstetrics, Gynaecology And Reproductive Medicine, 17(2): 58-61.
3. Sørensen HT, Sabroe S, Rothman KJ, Gillman M, Fischer P, Sørensen TI (1997). Relation between weight and length at birth and body mass index in young adulthood: cohort study. BMJ, 315(7116): 1137.
4. Wei JN, Sung FC, Li CY, et al. (2003). Low birth weight and high birth weight infants are both at an increased risk to have type 2 diabetes among schoolchildren in Taiwan. Diabetes Care, 26: 343–8.
5. Hermann GM, Dallas LM, Haskell SE, Roghair RD (2010). Neonatal macrosomia is an independent risk factor for adult metabolic syndrome. Neonatology, 98: 238–44.
6. Santangeli L, Sattar N, Huda SS (2015). Impact of maternal obesity on perinatal and childhood outcomes. Best Pract Res Clin Obstet Gynaecol, 29(3): 438-48
7. Monte S, Valenti O, Giorgio E, Renda E, Hysen Ei, Faraci M et al. (2011). Maternal weight gain during pregnancy and neonatal birth weight: a review of the literature. J Prenat Med. 5(2): 27–30.

8. Metzger BE, Lowe LP, Dyer AR, Trimble ER, Chaovarindr U, Coustan DR et al. (2008). HAPO Study Cooperative Research Group: Hyperglycemia and adverse pregnancy outcomes. N Engl J Med, 358(19): 1991-2002.
9. Cleary-Goldman J, Malone FD, Vidaver J, Ball RH, Nyberg DA, Comstock CH et al. (2005). Impact of Maternal Age on Obstetric Outcome. Obstet Gynecol, (5 Pt 1):983-90.
10. Chawla R, Badon SE, Rangarajan J, Reisetter AC, Armstrong LL, Lowe LP et al. (2014). Genetic risk score for prediction of newborn adiposity and large-for-gestational-age birth. J Clin Endocrinol Metab, 99(11): E2377-86.
11. Koyanagi A, Zhang J, Dagvadorj A, et al. (2013). Macrosomia in 23 developing countries: an analysis of a multicountry, facility-based, cross-sectional survey. Lancet, 381: 476–83.
12. Ahlsson F, Gustafsson J, Tuvemo T, Lundgren M (2007). Females born large for gestational age have a doubled risk of giving birth to large for gestational age infants. Acta Paediatr, 96(3): 358-62.
13. Tavares M, Rodrigues T, Cardoso F, Barros H, Leite LP (1996). Independent effect of maternal birth weight on infant birth weight. J Perinat Med, 24(4): 391-6.
14. Walsh JM, McAuliffe FM (2012). Prediction and prevention of the macrosomic fetus. Eur J Obstet Gynecol Reprod Biol, 162(2): 125-30.
15. Kgosidialwa O, Egan AM, Carmody L, Kirwan B, Gunning P, Dunne FP (2015). Treatment With Diet and Exercise for Women With Gestational Diabetes Mellitus Diagnosed Using IADPSG Criteria. J Clin Endocrinol Metab, 100(12): 4629-36.
16. American College of Obstetricians and Gynecologogists (2015). Physical Activity and Exercise During Pregnancy and the Postpartum Period. Committee Opinion Number 650. ACOG. Obstet Gynecol, 126: e135–42.
17. Duncome D, Skouteris H, Wertheim EH, Kelly L, Fraser V, Paxton SJ (2006). Vigorous exercise and birth outcomes in a sample of recreational exercisers, A prospective study across pregnancy. Australian and New Zealand Journal of Obstetrics and Gynecology, 46: 288-292.
18. Barakat R, Lucia A, Ruiz JR (2009). Resistance exercise training during pregnancy and newborn's birth size: a randomised controlled trial. Int J Obes (Lond), 33(9): 1048-57.
19. Ehrenberg HM, Mercer BM, Catalano PM (2004). The influence of obesity and diabetes on the prevalence of macrosomia. Am J Obstet Gynecol, 191(3): 964-8.

20. Haakstad LA, K (2011). Exercise in pregnant women and birth weight: a randomized controlled trial. BMC Pregnancy Childbirth, 11: 66.
21. Reid EW, McNeill JA, Alderdice FA, Tully MA, Holmes VA (2014). Physical activity, sedentary behaviour and fetal macrosomia in uncomplicated pregnancies: a prospective cohort study. Midwifery, 30(12): 1202-9.
22. Melzer K, Schutz Y, Soehnchen N, Othenin-Girard V, Martinez de Tejada B, Irion O (2010). Effects of recommended levels of physical activity on pregnancy outcomes. Am J Obstet Gynecol, 202(3): 266.e1-6.
23. Shapiro C, Sutija VG, Bush J (2000). Effect of maternal weight gain on infant birth weight. J Perinat Med, 28(6): 428-31.
24. Simmons D, Jelsma JG, Galjaard S, Devlieger R, van Assche A, Jans G et al. (2015). Results From a European Multicenter Randomized Trial of Physical Activity and/or Healthy Eating to Reduce the Risk of Gestational Diabetes Mellitus: The DALI Lifestyle Pilot. Diabetes Care, 38(9): 1650-6.
25. Colberg SR, Castorino K, Jovanovič L (2013). Prescribing physical activity to prevent and manage gestational diabetes. World J Diabetes, 4(6): 256-62.