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Original Research Article

Influence of diabetes on static efficiency of pregnant women's feet

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ABSTRACT

Introduction: During pregnancy, a range of hormonal and metabolic changes occurs in a woman's body. The body weight increase and the shift of the center of gravity are factors which have a disadvantageous effect on a pregnant woman's feet. Diabetes is another factor with a negative effect.

Aim: The aim of the study involved an assessment of the influence of pregnancy and diabetes on foot mechanics.

Material and methods: The study included pregnant healthy women, pregnant women suffering from type 1 diabetes and healthy women and women suffering from type 1 diabetes. To assess foot statics, a plantar analysis was performed, i.e. a print of the supporting part of the foot surface. The analysis was performed using a podoscope. The podoscope allowed for determining the distribution of foot pressure on the glass plate, on which the patient stood. The results analysis of the examination involved the determination of appropriate indices, including the length, the width of the foot, the Wejsflog index, the Sztriter–Godunov and the Clarke index.

Results and discussion: It was shown that pressure on individual areas of the feet increases during pregnancy. This is caused by an increase in the body weight. After delivery, pressure on individual areas of the feet decreases.

Conclusions: In type 1 diabetes, the pressure exerted on individual parts of the feet was higher than in healthy women and stress on the feet did not go back to the initial values after delivery. Some feet deformities in type 1 diabetes were lasting.

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1. Introduction

In Poland, there are 2.5 million diabetes sufferers in the general population. The number of persons diagnosed with diabetes increases every year. Owing to progress in diabetes treatment, it is complications that are the greatest problem now, including the diabetic foot syndrome. Poor diabetes management, neuropathy, ischemia, and inappropriate footwear very often lead to ulceration, which

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is a frequent cause of amputation of part of the foot or the entire foot.

Pregnancy is another factor which has a negative effect on diabetes. Embryo implantation and development, and subsequently fetus development, cause a range of hormonal and metabolic changes in a woman's body. During the initial period of pregnancy, the concentrations of estrogens, progesterone, cortisol, prolactin, placental lactogen, chorionic gonadotropin, and leptin increases.[1] Pregnancy development is accompanied by an increase in the woman's body weight mostly connected with fetal development. Initially, the fetal weight increases 10 g per week. In mid-pregnancy, the fetal growth accelerates significantly, reaching approx. 200 g per week in the period from week 24 to week 26. An increase in the body weight and the center of gravity shift are factors which have a disadvantageous effect on a pregnant woman's feet. The anatomical arches of the foot become lower. The excessively and incorrectly burdened muscle and ligament mechanism of the foot are exposed to damage.

Diseases accompanying pregnancy, including diabetes, are additional factors which have a disadvantageous effect on the foot condition. Pregnant women may suffer from impaired collagen metabolism and distribution, i.e. co-existence of two phenomena: excessive collagen accumulation in the subcutaneous and periarticular tissues and its glycation. They are the basis for pathologies of joints and periarticular tissues in diabetes. Feet, due to their complex structure and individual variability, are often subject to deformities, which inhibit their proper function. Appropriate preventive treatment may significantly reduce the frequency of foot defects and their severity.

2. Aim

The research conducted aimed at assessing the influence of pregnancy and diabetes on changes in foot biomechanics. Data on this subject available in the literature are scant and incomplete.

3. Material and methods

3.1. *Participants*

The study participants included pregnant women with type 1 diabetes, healthy pregnant women and both healthy women and women suffering from diabetes, who were not pregnant during the study period. Women suffering from gestational diabetes were treated with an appropriate diet, while women suffering from type 1 diabetes were treated with insulin. In all pregnant women, diabetes was metabolically stable.

Women with lesions resulting in pathological disorders of foot statics and mechanics, e.g. defects of the musculoskeletal system, considerable obesity, and neurological diseases including neuropathy, were excluded from the study. The women were divided into the following groups:

- Experimental Group 1 – including 16 women with physiological pregnancy,
- Experimental Group 2 – including 16 women with a few years' history (2–9 years) of type 1 diabetes treated with insulin,
- Experimental Group 3 – including 20 healthy non-pregnant women,
- Experimental Group 4 – including 20 women suffering from type 1 diabetes, who were not pregnant during the study.

All women participating in the study were aged from 18 to 35.

Table 1 – Age, height, weight and anthropometric data in groups of female subjects who were not pregnant.

	Not pregnant women (n = 20)	
	Healthy	With diabetes type 1
Age ± SD, year	26.75 ± 3.95	26.55 ± 4.61
Height ± SD, cm	164.43 ± 5.83	164.66 ± 5.03
Weight ± SD, kg	56.65 ± 4.96	60.65 ± 5.41
BMI, kg/m^2	20.53 ± 2.90	22.63 ± 2.52
HbA1c	–	5.38 ± 0.41
Glycemia before meal, mg%	–	118.23 ± 15.74
Glycemia after meal, mg%	–	114.04 ± 15.25

3.2. *Methods*

Upon acceptance to the study, each patient was subject to a physical examination and an interview as well as a neurological examination. An analysis of anthropometric data was performed for body weight and height.[2] On the basis of glycemia and hemoglobin measurements, the degree of metabolic stability of diabetes was assessed (Tables 1–3).

To assess foot statics, a plantar analysis of the foot was performed, i.e. a print of the supporting part of the foot surface. The examination was performed using a podoscope, i.e. an instrument built from appropriately arranged mirrors, a lighting lamp and a camera. The podoscope allowed for determining the distribution of foot pressure on the glass plate, on which the patient stood. The plantar analysis was performed using a podoscope by the ''Orthoprint'' company and software from the CQ Electronic System Artur Świerc company. The device was connected to a computer and it recorded the reflection of the feet of a standing person using a camera and transmitted the image to the computer. After analysis, the image was displayed in a graphic form on the monitor screen and next, it was saved to the computer

Table 2 – Weight, height, and age in the healthy pregnant women groups.

	Healthy pregnant women (n = 16)			
	I trimester	II trimester	III trimester	After birth
Weight ± SD, kg	58.91 ± 6.20	63.25 ± 5.01	68.91 ± 7.07	59.41 ± 4.54
Height ± SD, kg	164.43 ± 5.83			
Age ± SD, year	26.45 ± 3.43			

Table 3 – Age, height, weight and anthropometric data in groups of female subjects with diabetes type 1 and were pregnant.

	Women with diabetes type 1 (n = 16)			
	I trimester	II trimester	III trimester	After birth
Age ± SD, year		26.68 ± 3.45		
Height ± SD, cm		164.66 ± 5.03		
Weight ± SD, kg	60.06 ± 5.55	64.81 ± 2.66	68.25 ± 6.4	59.31 ± 5.12
BMI, kg/m^2	22.37 ± 2.39	24.43 ± 1.54	26.18 ± 3.79	23.8 ± 2.68
HbA1c	6.0 ± 5.55	6.48 ± 2.66	6.82 ± 0.61	5.93 ± 0.51
Glycemia before meal, mg%	106.41 ± 10.42	115.17 ± 6.54	119.54 ± 9.53	107.68 ± 9.64
Glycemia after meal, mg%	106.70 ± 10.64	110.79 ± 7.22	114.41 ± 9.61	102.83 ± 9.02

memory. The analysis of the research result involved determination of relevant indices and angles, which allowed for the assessment of the static burden of the foot. Owing to data obtained in the podoscopic examination, we received information necessary for proper diagnosis of foot defects. We could diagnose the presence of a longitudinal flat foot, transverse flatfoot, valgosity and toe varosity. On the basis of the results in the analysis, it was also possible to make individual orthopedic inserts or orthopedic shoes.

4. Results

The plantar examination of the feet in the control group of healthy women and non-pregnant women suffering from type 1 diabetes showed that in healthy women the right foot was by 7.3 mm longer and the left foot was by 8.5 mm longer. Apart from this, there were no significant differences between the values of the indices under analysis in both groups. The results of the research are presented in Tables 4–8.

The planar analysis in the group of healthy women in subsequent trimesters of pregnancy revealed a gradual decrease in the Wejsflog index values for both feet, an increase in the Sztriter–Godunov index and a decrease in the Clarke's angle for both feet, which confirmed the lowering of transverse and longitudinal arches of feet in subsequent trimesters of pregnancy. After delivery, these changes subsided. Similar changes were observed in the planar analysis of feet of healthy women suffering from type 1 diabetes. In a comparison of healthy pregnant women and pregnant women suffering from diabetes, it was found that in the diabetes group, the left foot was longer and its longitudinal arch was lower, while both arches were lower in the right foot – both the transverse and the longitudinal one throughout pregnancy. After delivery, the Wejsflog index and Clarke's index of the right foot became reduced in the group of women suffering from type 1 diabetes as compared to the period before pregnancy. In the third trimester of pregnancy, greater lowering of the transverse arch of the right foot was found in women with type 1 diabetes. However, this change subsided after delivery.

5. Discussion

Feet support human weight. We use them during everyday activities. The complicated system of bones, joints, ligaments and muscles determines their shape and motion. They are the part of the human body that is most injury-prone. The condition of feet is determined by numerous factors, including activity, occupation, footwear, pregnancy, diseases, etc. We included two factors influencing the condition of feet – pregnancy and diabetes. Poorly managed diabetes leads to

Table 4 – Comparison of examined feet indexes in healthy women and women with type 1 diabetes without pregnancy.

Examined feet indexes	Healthy women without pregnancy (n = 20)		Women with type 1 diabetes without pregnancy (n = 20)	
	Mean ± SD	Me	Mean ± SD	Me
Length of the foot, mm				
Right foot	232.05 ± 7.49	235.00	224.75 ± 10.60	225.00
Left foot	230.20 ± 7.17	232.00	221.70 ± 10.33	220.50
Width of the foot, mm				
Right foot	89.25 ± 3.64	89.00	88.15 ± 4.31	87.50
Left foot	89.80 ± 4.12	91.00	87.05 ± 6.07	86.00
Wejsfloga index				
Right foot	2.56 ± 0.11	2.56	2.51 ± 0.09	2.54
Left foot	2.57 ± 0.13	2.56	2.58 ± 0.09	2.58
Sztriter–Godunov index				
Right foot	0.38 ± 0.06	0.40	0.38 ± 0.07	0.39
Left foot	0.34 ± 0.07	0.36	0.39 ± 0.13	0.37
Clarke's angle index, degrees				
Right foot	47.48 ± 7.70	50.20	46.52 ± 6.97	48.85
Left foot	45.04 ± 7.67	46.45	45.50 ± 6.66	45.75

Table 5 – Comparison of examined feet indicators in the first trimester of pregnancy in healthy women and women with type 1 diabetes.

Examined feet indexes	Healthy pregnant women (n = 16)		Pregnant women with type 1 diabetes (n = 16)	
	Mean ± SD	Me	Mean ± SD	Me
Length of the foot, mm				
Right foot	229.33 ± 8.24	227.00	234.12 ± 10.08	232.50
Left foot	227.50 ± 2.23	227.00	231.00 ± 8.80	229.5
Width of the foot, mm				
Right foot	90.91 ± 4.60	91.00	88.31 ± 4.22	87.00
Left foot	88.83 ± 5.20	90.00	86.68 ± 4.33	86.00
Wejsfloga index				
Right foot	2.68 ± 0.13	2.67	2.65 ± 0.12	2.62
Left foot	2.61 ± 0.13	2.62	2.71 ± 0.13	2.74
Sztriter–Godunov index				
Right foot	0.34 ± 0.05	0.36	0.36 ± 0.09	0.37
Left foot	0.30 ± 0.06	0.33	0.36 ± 0.07	0.35
Clarke's angle index, degrees				
Right foot	51.07 ± 4.00	52.90	47.68 ± 5.48	46.60
Left foot	52.56 ± 4.39	54.20	48.96 ± 4.95	47.90

complications, such as the diabetic foot syndrome, which causes ulceration, which is difficult to heal and, in turn, can lead to amputation of the whole foot.

Pregnancy is another factor with a negative effect on feet. Changes occurring in a pregnant woman's body allow for embryo implantation and development. Unfortunately, they are accompanied by an increase in the body weight and the center of gravity shift, which have a negative influence on a pregnant woman's feet. A small number of reports in professional literature on the influence of pregnancy on foot biomechanics both in healthy women and in women suffering from diabetes was a signal that it is worthwhile to perform a deeper analysis of this problem. The research was aimed at assessing the influence of diabetes and pregnancy on the degree of foot deformity in the groups under analysis. It was decided to assess the degree of load on individual zones of the sole part of the foot and determine the most crucial places. Women suffering from type 1 diabetes and gestational diabetes as well as healthy pregnant women took part in the study. Apart from this, non-pregnant women, both healthy and suffering from type 1 diabetes, participated in the study as control groups. All women were assigned to one of the 5 experimental groups. Pregnant women were subjected to the examination several times, in each subsequent trimester of the pregnancy, and next after delivery. The women, who were not pregnant, were examined once upon their inclusion in the study. Women with anatomical changes in feet resulting in mechanics disorders, such as musculoskeletal defects, neurological diseases resulting in walking difficulties, severe obesity, etc., were excluded from the study. The planar analysis with the use of a podoscope was characterized by a high degree of repeatability, which means that it was

Table 6 – Comparison of examined feet indicators in the second trimester of pregnancy in healthy women and women with type 1 diabetes.

Examined feet indexes	Healthy pregnant women (n = 16)		Pregnant women with type 1 diabetes (n = 16)	
	Mean ± SD	Me	Mean ± SD	Me
Length of the foot, mm				
Right foot	230.50 ± 8.97	228.00	232.00 ± 7.49	232.00
Left foot	226.66 ± 3.79	223.00	228.12 ± 6.90	227.50
Width of the foot, mm				
Right foot	94.50 ± 5.30	94.00	89.06 ± 4.75	88.50
Left foot	91.33 ± 5.26	92.00	87.37 ± 5.05	87.00
Wejsfloga index				
Right foot	2.50 ± 0.14	2.47	2.48 ± 0.06	2.50
Left foot	2.45 ± 0.14	2.46	2.43 ± 0.05	2.43
Sztriter–Godunov index				
Right foot	0.42 ± 0.07	0.45	0.43 ± 0.04	0.42
Left foot	0.39 ± 0.07	0.41	0.40 ± 0.12	0.42
Clarke's angle index, degrees				
Right foot	44.72 ± 3.18	43.20	42.20 ± 2.62	42.30
Left foot	46.62 ± 5.55	44.75	44.65 ± 4.30	44.80

Table 7 – Comparison of the examined feet indicators in the third trimester of pregnancy in healthy women and women with type 1 diabetes.

Examined feet indexes	Healthy pregnant women (n = 16)		Pregnant women with type 1 diabetes (n = 16)	
	Mean ± SD	Me	Mean ± SD	Me
Length of the foot, mm				
Right foot	230.83 ± 8.49	231.50	230.75 ± 8.20	230.50
Left foot	227.83 ± 6.10	230.00	227.68 ± 7.76	227.00
Width of the foot, mm				
Right foot	92.75 ± 5.84	93.00	90.37 ± 4.81	89.50
Left foot	92.08 ± 5.17	92.00	89.56 ± 5.11	89.00
Wejsfloga index				
Right foot	2.37 ± 0.08	2.37	2.40 ± 0.13	2.42
Left foot	2.44 ± 0.08	2.43	2.32 ± 0.14	2.33
Width of the left heel, mm	51.83 ± 3.99	52.50	50.12 ± 3.93	50.00
Sztriter–Godunov index				
Right foot	0.45 ± 0.04	0.46	0.49 ± 0.06	0.50
Left foot	0.42 ± 0.04	0.42	0.44 ± 0.07	0.44
Clarke's angle index, degrees				
Right foot	38.75 ± 3.64	39.45	40.38 ± 5.90	39.80
Left foot	41.04 ± 4.69	41.60	43.56 ± 7.63	42.85

Table 8 – Comparison of the examined feet indicators after birth in healthy women and women with type 1 diabetes.

Examined feet indexes	Healthy pregnant women N = 16		Pregnant women with type 1 diabetes N = 16	
	Mean ± SD	Me	Mean ± SD	Mean ± SD
Length of the foot, mm				
Right foot	229.50 ± 7.67	230.50	229.50 ± 9.46	230.00
Left foot	227.25 ± 6.13	227.00	226.50 ± 9.59	227.00
Width of the foot, mm				
Right foot	92.25 ± 4.63	94.00	89.50 ± 3.22	90.00
Left foot	91.25 ± 4.67	92.00	89.25 ± 3.90	89.00
Wejsfloga index				
Right foot	2.58 ± 0.09	2.55	2.69 ± 0.12	2.68
Left foot	2.63 ± 0.11	2.62	2.62 ± 0.10	2.59
Sztriter–Godunov index				
Right foot	0.36 ± 0.06	0.37	0.38 ± 0.05	0.39
Left foot	0.34 ± 0.07	0.34	0.35 ± 0.06	0.35
Clarke's angle index, degrees				
Right foot	50.66 ± 3.81	50.50	45.80 ± 3.20	46.35
Left foot	51.12 ± 5.55	51.50	47.63 ± 3.43	47.90

objective. This mostly applies to a small degree of deformities, which could have been overlooked by the examining physician without the aid of the podoscope. A computer analysis of feet made it possible to obtain an accurate image of the support surface of the foot (podoscopic footprint), owing to which information about the spatial shape of the foot arch was obtained. The data obtained in this way provided information necessary for proper diagnosis of foot defects (longitudinal flat foot, transverse flatfoot, valgosity or toe varosity). In summary, the pressure on individual areas of the feet increases during pregnancy. This is probably caused by an increase in the body weight of pregnant women. After delivery, the load on individual foot zones decreases, which is connected with an abrupt decrease in the body weight after delivery.[3–5]

In type 1 diabetes, the pressure exerted on individual parts of the feet was higher than in healthy women and the stress on the feet did not go back to the initial values after delivery. Some feet deformities in type 1 diabetes were lasting, despite appropriate diabetes management. Probably, collagen metabolism and distribution disorders, glycation, formation of collagen deposits characterized by lower solubility and a lower susceptibility to enzymatic digestion result in impaired articular mobility and foot deformities. The research conducted shows that not all foot deformity in women after delivery subsided completely. It is a signal that regular check-ups of pregnant women's feet should be performed in the subsequent pregnancy trimesters as well as after delivery. If any irregularities are found, individual correction of the foot statics is necessary by means of individually selected correction inserts to prevent lasting effects of deformities after delivery.

6. Conclusions

In summary, the pressure on individual areas of the feet increases during pregnancy. This is caused by an increase in the

body weight of pregnant women. After delivery, the burden on individual foot zones decreases, which is connected with an abrupt decrease in the body weight after delivery. The research conducted shows that not all foot deformity in women after delivery subsided completely. It is a signal that regular check-ups of pregnant women's feet should be performed in the subsequent pregnancy trimesters as well as after delivery. If any irregularities are discovered, correction of foot statics is necessary, which requires specialist consultations and rehabilitation treatment. Owing to the latest kinesitherapy methods, modern rehabilitation procedures used at an early period allow for restoring the physiological functions of feet completely.

Conflict of interest

None declared.

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