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Cambios en la alineación de las extremidades inferiores durante la marcha en fases avanzadas del embarazo y el efecto de calzado especial

Changes in the lower limb alignment during the gait in advanced phases of pregnancy and the effect of special footwear

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Abstract: The hip, knee and foot pain are common complaints during pregnancy as pregnancy affects the musculoskeletal health. The purpose of the study was to investigate the pregnancy gait adaptations and the effect of special footwear. 16 pregnant women divided into a control and experimental group, who obtained the special footwear, participating at 27, 32 and 37 gestational weeks in data collection sessions. At each session participants were asked to go barefoot in a space captured by the Simi Motion®. To compare the differences between different collection sessions, effect size obtained by Cohen's *d* was used. Results of this study showed, that using the tested footwear enabled a verticalization of the pelvic segment, increase of the maximum hip extension angle, reduction of foot-floor angle and maintaining the same height of the knee during walking in the experimental group, possibly decreasing the risk of pain development in these body segments during pregnancy.
Keywords: Kinematic Analysis, Gait, Pregnancy, Special footwear.
Resumen: El dolor de cadera, rodilla y pie son problemas comunes durante el embarazo, ya que el embarazo afecta la salud musculo esquelética. El propósito del estudio fue investigar las adaptaciones de la marcha en el embarazo y el efecto de calzado especial. 16 mujeres embarazadas fueron divididas en un grupo control y otro experimental, obteniendo las de este último el calzado especial. Participaron en las tomas de datos en las semanas de embarazo 27, 32 y 37. En cada sesión se pidió a las participantes andar descalzas en un espacio monitorizado por el Simi Motion®. Para comparar las diferencias entre las diferentes sesiones de evaluación, se utilizó el tamaño de efecto obtenido por la *d* de Cohen. Los resultados de este estudio mostraron que, en el grupo experimental, el uso del calzado especial probado permitió una verticalización del segmento pélvico, aumento del ángulo máximo de extensión de la cadera, reducción del ángulo pie-suelo y mantenimiento de la misma altura de la rodilla durante la marcha, posiblemente disminuyendo el riesgo de desarrollo de dolor en estos segmentos corporales durante el embarazo.
Palabras clave: Análisis Cinemático, Marcha, Embarazo, Calzado especial.

Background

An array of changes occurs during pregnancy in the woman's body to enable the development of the embryo and fetus and the consequent delivery. During pregnancy, particularly in its advanced stages, those changes affect locomotion due to the body weight increase, ventral uterine growth and the hormonal loosening of joints caused by the higher estrogen and relax in production (Čech, et al., 2009; Maršál, 2014). Primarily, the hormonal loosening of connective tissue structures take placed in the pelvic girdle, but its secondary effect leads to the loosening of the foot arch ligaments. Along with the increasing body mass it may cause a decrease in transverse and longitudinal foot arches and associated changes in plantar pressure distribution and lower extremity alignment. Additionally, the hormonal changes in the pregnant body lead to a muscle weakening, especially in the breast and abdomen area. Those changes affect the gait, balance, the risk of falling and pain occurrence during pregnancy and some of them persist in the subsequent postpartum period (Segal & Chu, 2015; Ribeiro et al., 2013).

In order to maintain the gait pattern, i.e. stride length, cadence and joint angles; unchanged during pregnancy, an increased use of the hip extensors, hip abductors and plantar flexion muscles were observed in the gait of pregnant women. Despite the attempt, the gait pattern alters with advancing phases of pregnancy (Segal & Chu, 2015; Foti et al., 2000). The majority of previous studies shows an increased time of double support phase, a significant decrease in the step length, an increased in the step width and a decrease in velocity. However, other aspects of pregnancy gait show a large variability in observations and often contradictory findings (Błaszczyk et al. 2016, McCrory et al., 2014; Foti et al., 2000; Gilleard, 2013; Forczek & Staszkiewicz, 2012; Wu et al., 2004; Bird et al. 1999; Branco et al., 2013).

Nevertheless, musculoskeletal health is affected by changes generated during the pregnancy and up to 75 % of pregnant woman complain about the back and foot pain, more

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than 50 % of pregnant women report hip pain and the prevalence of knee pain during pregnancy is about 22 % (Karadag-Saygi et al., 2010; Ponnapula & Boberg, 2010). Therefore, the purpose of this study was to investigate the gait adaptation during advanced stages of pregnancy and the possible beneficial effect of special footwear.

Participants and Methods

The research sample consisted of 20 pregnant women, 16 of them participated in all three data collection sessions. The data collection sessions were performed at the 27, 32 and 37 gestational weeks (g.w.) at the Laboratory of Biomotorics, Faculty of Sports Studies, Masaryk University, Brno, Czech Republic between January and June 2016. A reduced number of participants in later stages of pregnancy was caused by preterm delivery, or a risk pregnancy condition and the associated problems of pregnant women with transportation to the last measurement. During the first measurement participants were randomly divided into a control (n=10) and experimental (n=10) group. All data were collected from 9 pregnant women from the control group and 7 pregnant women from the experimental group. Their characteristics are shown in Table 1. The inclusion criteria were a suitable stage of pregnancy and no locomotion restrictions. The informed consent was obtained from all participants prior to the first data collection session. The study was approved by the Ethical board of the Faculty of Sports Studies, Masaryk University, Brno, Czech Republic.

Table 1. The mean body mass at particular data collection sessions (kg), height (cm) and age (years) at the first data collection for the control and experimental group (± standard deviation).

	Age	Height	Body mass at 27 g.w.	Body mass at 32 g.w.	Body mass at 37 g.w.
Experimental group (n=7)	33.86±3.14	165.00±9.98	72.28±7.95	74.55±7.28	77.94±7.56
Control group (n=9)	31.78±2.70	170.11±4.33	68.70±3.45	71.00±3.45	73.44±2.98

The experimental group received the tested footwear within 10 days after the first data collection session with an instruction to use it daily. The tested footwear J Hanák R, Ltd. consisted of slippers for a home use and sneakers or winter shoes for outdoor activities depending on the season. The tested footwear consists of patented insoles (Figure 1) and its most prominent feature is a depression under the first metatarsophalangeal joint to promote a more balanced loading when walking. Furthermore, a depression under the heel portion enables correction of the calcaneus position. The footwear is claimed to stimulate the muscles and connective tissue structures of both, the longitudinal and transverse arch (J Hanák R, Ltd.)

Figure 1. Tested insoles (J Hanák R, Ltd.).

Kinematic analysis is a commonly used method for movement analyses as it enables movement rationalization and evaluation (Krska et al., 2014; Janura & Zahálka 2004). 13 markers placed on the anthropometrical points acromiale, iliospinale anterius, trochanterion, tibiale laterale, malleolus lateralis, calcaneus, big toe and 5th lumbar vertebra were used for this study. This marker set was placed on the skin of participants using retro-reflective markers. Subjects wore a fitting t-shirt and underwear. During the data collection, participants were asked to go barefoot through a seven meter long path in a space captured by 8 cameras using the Simi Motion® hardware and software at their preferred speed. The first two trials were for training in order to set the natural walking condition, the third record, its second step cycle, was used for markers digitalization and further data analysis. The markers digitalization of one step of the right and left limb was done prior the 3D model creation. The beginning of the step was determined by the heel strike. The X-axis was pointing forward, Y-axis was pointing horizontally and the Z-axis was pointing upward.

Data analysis

A 3D model of gait at the 27, 32 and 37 weeks of gestation were created for all 16 participants. Following variables were exported from the model and their values and are shown in Table 2:

Pelvic tilt (an angle defined by the markers L5, trochanterion and XY plane, at the moment of the first heel contact); hip extension (maximal peak of an angle defined by the markers acromiale, trochanterion, tibiale laterale); knee joint height (maximal height of the marker tibiale laterale); foot-floor angle (maximal peak of an angle defined by the markers calcaneus, big toe and XY plane); and step width (a mean width during the gait cycle between right and left malleolus lateralis markers).

Table 2. Mean values and their standard deviation (SD) of selected variables for the control and experimental group.

		Pelvic tilt	Hip extension	Knee joint height	Foot-floor angle	Step width
Control group	27 g.w.	33.19	171.16	0.47	60.71	0.16
	SD	5.07	2.28	0.05	10.49	0.02
	32 g.w.	26.61	169.72	0.5	63.73	0.16
	SD	8.94	1.82	0.04	7.64	0.02
	37 g.w.	24	169.81	0.51	57.55	0.15
	SD	10.83	2	0.05	12.22	0.03
Experimental group	27 g.w.	23.49	167.63	0.46	65.09	0.16
	SD	9.06	4.13	0.04	7.22	0.03
	32 g.w.	27.43	168.95	0.46	61.37	0.16
	SD	7.69	3.86	0.04	7.39	0.02
	37 g.w.	28.34	171.32	0.46	58.61	0.18
	SD	9.81	4.13	0.06	11.84	0.02

To compare the differences between different collection sessions for the experimental and control group, effect size obtained by Cohen's d was used, as the number of participants is not suitable for a statistical analysis. Cohen's d is interpreted as > 0.20 small, > 0.50 medium, clinically significant, > 0.80 large effect (Cohen, 1977).

Results

A decrease in pelvic tilt, an angle measured at the moment of the first heel contact, was observed in the control group at advanced phases of pregnancy together with decreasing values of the hip maximal extension. In contrary, for the experimental group the maximum angle of the hip extension increased (Table 3 and 4). The foot-floor angle was decreasing with the advancing stages of pregnancy in both groups (Table 5). Similarly, changes in the width of the step with advancing stages of pregnancy did reach significance by effect size in both groups (Table 6). In contrast to the control group experimental group maintained the same height of the knee during walking (Table 7).

Table 3. Cohen's d values and their confidence intervals (CI) of differences in pelvic tilt between the 27, 32 and 37 gestational weeks. Highlighted values achieved the effect size significance.

	27-32 g.w.		32-37 g.w.		27-37g.w.	
Pelvic tilt	Cohen's d	CI	Cohen's d	CI	Cohen's d	CI
Control group	**0,94**	(-2,37; 6,78)	**0,26**	(-5,58; 7,34)	**1,16**	(-2,16; 8,23)
Experimental group	**-0,47**	(-7,18; 5,23)	-0,1	(-5,80; 7,16)	**-0,51**	(7,23; 6,75)

Table 4. Cohen's d values and their confidence intervals (CI) of differences in hip extension between the 27, 32 and 37 gestational weeks. Highlighted values achieved the effect size significance.

	27-32 g.w.		32-37 g.w.		27-37g.w.	
Hip extension	Cohen's d	CI	Cohen's d	CI	Cohen's d	CI
Control group	**0,7**	(-0,79; 1,89)	**0,63**	(-0,86; 1,94)	-0,05	(-1,24; 1,26)
Experimental group	**-0,33**	(-3,39; 2,53)	**-0,59**	(-3,45; 2,47)	**-0,89**	(-3,95; 2,17)

Table 5. Cohen's d values and their confidence intervals (CI) of differences in foot-floor angle between the 27, 32 and 37 gestational weeks. Highlighted values achieved the effect size significance.

	27-32 g.w.		32-37 g.w.		27-37g.w.	
Foot-floor angle	Cohen's d	CI	Cohen's d	CI	Cohen's d	CI
Control group	**-0,33**	(-7,19; 4,66)	**0,62**	(-4,37; 8,61)	**0,28**	(-6,58; 8,26)
Experimental group	**0,51**	(-4,84; 5,98)	**0,29**	(-5,19; 9,06)	**0,68**	(-4,67; 9,45)

Table 6. Cohen's d values and their confidence intervals (CI) of differences in step width between the 27, 32 and 37 gestational weeks. Highlighted values achieved the effect size significance.

	27-32 g.w.		32-37 g.w.		27-37g.w.	
Step width	Cohen's d	CI	Cohen's d	CI	Cohen's d	CI
Control group	0	(-0,01; 0,01)	**0,4**	(0,39; 0,42)	**0,4**	(0,39; 0,42)
Experimental group	0	(-0,02; 0,01)	**-1**	(-1,01; -0,99)	**-0,8**	(-0,82; -0,79)

Table 7. Cohen's d values and their confidence intervals (CI) of differences in knee joint height between the 27, 32 and 37 gestational weeks. Highlighted values achieved the effect size significance.

	27-32 g.w.		32-37 g.w.		27-37g.w.	
Knee joint height	Cohen's d	CI	Cohen's d	CI	Cohen's d	CI
Control group	**-0,67**	(-0,70; -0,64)	**-0,8**	(-0,83; -0,77)	**-0,22**	(-0,25; -0,19)
Experimental group	0	(-0,03; 0,03)	0	(-0,03; 0,04)	0	(-0,03; 0,04)

Discussion

During pregnancy the low back, hip, knee and foot pain are a common complaints (Karadag-Saygi et al., 2010; Ponnapula & Boberg, 2010). However, a better understanding the pregnancy changes, which are affecting the musculoskeletal health, may bring prevention opportunities and treatment. Therefore, the purpose of the study was to investigate the gait adaptation during advanced stages of pregnancy and the possible beneficial effect of special footwear.

In the experimental group, who wore the tested footwear, an increase in maximum angle of the hip extension was observed. The increased hip extension angle may help to maintain the vertical position of the pelvis. On the contrary, decreased pelvic tilt, an angle measured at the moment of the first heel contact, was observed at advanced phases of pregnancy in the control group and seems to compensate decreased values of the hip maximal extension. In previous studies altered patterns of motion of pelvis segment, especially the increased anterior pelvic tilt, have been associated with the development of back pain and pelvic girdle pain during pregnancy (Ribeiro, et al., 2013; Foti et al, 2000; McCrory et al., 2014; Gilleard, 2013).

Changes in the width of the step with advancing stages of pregnancy did reach significance by effect size in both groups. Also the majority of previous studies shows an increased step width during pregnancy (Błaszczyk et al. 2016, McCrory et al., 2014; Foti et al., 2000; Gilleard, 2013; Forczek & Staszkiewicz, 2012; Branco et al., 2013). The wider step width relates to an increased pelvic width and to a redistribution of body mass (Gilleard, 2013; Foti et al., 2000).

Similarly, the foot-floor angle was decreasing with the advancing stages of pregnancy in both groups. The observed decrease of this angle, which was significant by effect size, indicates to a substantial shortening of the stride length associated with the gait velocity decrease, described also in previous studies during pregnancy (Błaszczyk et al. 2016; Forczek & Staszkiewicz, 2012). Clinically significant effect of the foot-floor angle changes was observed in the experimental group after the tested footwear introduction, indicating an increased contact time of the forefoot with the floor associated with the foot muscles activation.

The effect of different types of footwear and insoles during pregnancy has been tested in previous studies. Their results show, that special footwear contributes to a decrease of the excessive load on the feet measured by plantar pressure and an improvement of the foot blood circulation (Jang et al., 2010; Marques et al., 2005); however, the number of studies of their effect on the lower limb alignment during the gait is lacking. In this study the effect of the tested footwear was observed in the experimental group by verticalization in the sagittal plane of pelvis position during the heel contact with the floor. Related changes were observed by the increase of the maximum hip extension angle, reduced foot-floor angle and by maintaining the same height of the knee during walking. These changes may reduce the excessive load on lower limb during pregnancy and decrease the risk of pain development.

Conclusions

Pregnancy, as a demanding period of life, generates many changes affecting the musculoskeletal health and understanding these changes may bring both, prevention opportunities and treatment. This 3D kinematic gait study showed a different pattern of changes during pregnancy in pelvis position in the control and experimental group. Using the tested footwear enabled a verticalization of the pelvic segment at the heel strike phase of the gait cycle and increasing the angle of maximal hip extension, possibly decreasing the risk of pain development in this body segments. Still, future studies investigating the possible beneficial effect of tested footwear on the lower extremity alignment on a larger sample are necessary.

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