Assessment of COP characteristics and force-time changes during walking in the third trimester of pregnancy

Ondřej Mikeska, Martin Zvonař, Marta Gimunová

Faculty of Sports Studies, Masaryk University, Brno, Czech Republic

Abstract

Purpose: *The primary aim of this study was to analyse the COP characteristics and force-time changes during walking between weeks 27 and 36 of pregnancy. The secondary objective was to verify the influence of the specific orthopaedic shoes that were given to the experimental group. The experimental group wore patented J Hanák R biomechanical footwear and insoles, which are designed to help with redistribution of forces acting on foot, to support both longitudinal and transverse arches of the foot and to strengthen the foot muscles during movement.*

Methods: *Seventy-three pregnant women participated in this study. This group was random divided into the experimental group (35 pregnant women) wearing specific orthopaedic shoes and the control group (38 pregnant women). The motor task consisted of five gait trials where two foot prints for each leg were always recorded. The participants started barefoot walking 3 m ahead of the pressure platform and finished the trial 1 m after the end of the platform in order to preserve acceleration and deceleration in gait. Participants walked at their own preferred velocity. All pedobarometric parameters were registered by Emed walkway – trademark of Novel GmbH in Munich, Germany. Data processing was divided to two scrips. The first script processed data to these variables (COP characteristics): Centre of pressure index (COPI), centre of pressure excursion index (COPEI), distance (D) of COP, maximum velocity (MaV) and mean velocity (MeV) of COP. The second script processed data for ten pre-defined areas of the foot: hindfoot, midfoot, MH1-5 – metatarsal heads, big toe, second toe, toes 3, 4 and 5 with these applied variables (force-time characteristics): Force-time integral (FTI) and contact time (CT).*

Results: *For the experimental group, in comparison between 27th week and the 36th week of gestation, we can find lower COPI for both feet, significantly only for the left foot ($p = 0.04$). Also, significant difference in COPEI ($p = 0.03$, $p = 0.03$) for both feet was found. In comparison pre and post measurement we found higher values of parameters COPI and COPEI and that indicates more lateral weight shifting during the last trimester. We can distinctly register extension of D, especially for the left foot ($p = 0.04$). Changes in velocity of COP indicate that MaV was increased for both feet ($p = 0.00$, $p = 0.00$) and MeV was significantly increased only for the right foot ($p = 0.00$) in the 36 week of pregnancy. For the control group, we found no significant changes in COPI, COPEI or COP. MaV and MeV of COP were significantly increased for both feet in the 36 week of pregnancy ($p = 0.02$, $p = 0.00$, $p = 0.01$, $p = 0.00$). Higher values of MaV and MeV indicate that pregnant women accelerated their walking in the 36 week of pregnancy. Further, force-time characteristics in most cases did not reveal statistically significant changes in the last trimester.*

Conclusion: *Over the last three months of pregnancy, significant observable changes can be found, especially through COP parameters of the experimental and the control group. We found out that the specific orthopaedic shoes given to the experimental group influenced the trajectory of COP, which could have positive health aspects. Further, certain conflicting results of our study in comparison with other similar studies only confirm that individual biomechanic and physiological developments in pregnancy affect the kinematic and kinetic aspects of walking differently.*

Key Words: *Center of pressure, pregnancy, gait, feet*

INTRODUCTION

Pregnancy is a phase in women's lives when physical and hormonal changes occur, including weight gain, increased ligament laxity, changes in the size of the contact areas of the foot, changes in the velocity of gait, disturbed neuromuscular control and increased muscle weakness (Titianova, Mateev & Tarkka 2004). These changes may lead to an increase in postural or dynamic instability (Bertuit, Leyh, Rooze & Feipel 2017). Changes in gait and postural control during pregnancy can lead to a higher risk of falls during walking relative to non-pregnant women (Krkeljas, 2018). The risk of falling can reach up to 27% (Dunning et al., 2003). Moreover, the risk of falling is significantly higher in the third trimester of pregnancy (Inanir, Cakmak, Hisim & Demirturk, 2014). Therefore, it is important to observe and analyse kinetics and kinematics aspects in the gait of pregnant women.

Kinematic gait profile has unique development during a pregnancy and based on a several authors, the results of spatial and temporal gait parameters during pregnancy may be different. According Galleher (2001), the gait remains unchanged with similar speed, frequency, stride length and stable kinematic parameters.

On the other side, gait goes through significant changes: gait speed and step length are reduced, there is an increase of stance phase and double-support phase (Błaszczyk, Opala-Berdzik & Plewa, 2016), a decrease of swing phase (Bertuit, Feipel & Rooze, 2015; Forczek & Staszkiewicz, 2012) and a lower frequency of steps (Forczek & Staszkiewicz, 2012). Also, we can register an increase of step width (up to 50 %) in late pregnancy (Osman & Ghazali, 2002; Lymbery & Gilleard, 2005). So, as we can see, there exists a large variability in gait strategies and individual musculoskeletal adaptations in a pregnancy (Forczek & Staszkiewicz, 2012; Galleher, 2001). The center of pressure (COP) characteristics seem to be appropriate for assessing gait (Santos et al., 2008; Oliveira et al., 2009). The center of pressure is influenced by gait velocity, frequency, cycle length, the distribution of the mass of the subject and weight (Titianova, Mateev & Tarkka, 2004).

The COP velocity is lower in late pregnancy (pregnant women: 0.28 ± 0.03 m/s, control group: 0.33 ± 0.04 m/s) (Bertuit, Leyh, Rooze, & Feipel, 2017). Overall, the typical walking profile tends to increase single stance duration and double stance duration in the third trimester compared to the earlier trimesters (Ramachandra, Maiya, Kumar & Kamath, 2018; Błaszczyk, Opala-Berdzik & Plewa, 2016) and this adjustment is for gait stability improvement (Błaszczyk, Opala-Berdzik & Plewa, 2016).

One of the most significant changes is body mass gain (Opala-Berdzik, Bacik & Kurkowska, 2009; Ogamba et al., 2016) The normal body mass gain during pregnancy ranges from 11.3 kg – 15.9 kg (Vanstone et al., 2016) and abdominal mass increases by at least 31 % (6.8 kg) (Whitcome, Shapiro & Lieberman, 2007).

The primary aim of this study was to analyse the COP characteristics and force-time changes during walking between weeks 27 and 36 of pregnancy. The secondary objective was to verify the influence of the specific orthopaedic shoes that were given to the experimental group.

MATERIALS AND METHODS

Participants

73 of 100 pregnant women participated in this study. The rest of the pregnant women (27) did not finish all measurements due premature childbirth or health problems. All pregnant women were addressed based on advertising leaflets in the gynecological departments in Brno. The age (years), height (cm) and body mass (kg) of group are shown in Tables 1. This group was random divided into the experimental group (35 pregnant women) wearing specific orthopaedic shoes developed in cooperation between Masaryk University and J Hanák R and the control group (38 pregnant women). The inclusion criterion was a low-risk pregnancy and the period before the third trimester, whereas the exclusion criteria included any orthopaedic or neurological disorders that could influence the gait. The measurements were conducted at the beginning of the 27th week of gestation (pre-measurement) and at the 36th week of gestation (post-measurement). The experimental group wore special biomechanical shoes during this period. Prior to the study, participants were informed about the measurement procedure and they signed an informed consent. The protocol was approved by the Research Ethics Committee of the Masaryk University, Brno, Czech Republic.

Tab. 1: Participants' characteristics

	Age	Height	Weight 27 week	Weight 32 week	Weight 38 week
Experimental group	30.6 ± 4.2	167.2 ± 7.7	73.5 ± 10.5	76.2 ± 9.4	78.9 ± 10.1
Control group	30.7 ± 3.2	168.8 ± 6.7	73.4 ± 9.1	75.7 ± 10.0	78.4 ±1 0.3

Materials

All pedobarometric parameters were registered by Emed walkway – trademark of Novel GmbH in Munich, Germany. The platform provide accurate, reliable information for the analysis of foot function and diagnosis of foot pathologies. Specifications: (Emed-xl, platform size: 1,529 x 504 mm^2, sensor area: 1,440 x 440mm^2, number of sensors: 25,344, sensor resolution: 4 sensors/cm^2, recording frequency: 100 Hz, measuring range: 10 – 1,270 kPa, pressure threshold: 10 kPa). Data were collected at the laboratory of kinanthropological research on the campus of Masaryk University of Brno, Czech Republic.

Methods

The motor task consisted of 5 gait trials where two footprints for each leg were always recorded. The participants started barefoot walking 3 m ahead of the pressure platform and finished the trial 1 m after the end of the platform in order to preserve acceleration and deceleration in gait. Participants walked at their own preferred velocity. Data was collected from all 5 valid gait trials. This cycle of 5 gait trials always consisted of 10 steps (five steps with the right/left foot). The experimental group was wearing specific orthopaedic shoes 1–2 weeks after first measurements. Based on random selection, chosen women have got 2 pairs of experimental shoes, 1 pair for home movement, 1 pair for movement in outside. The condition was that they had to wear shoes every day.

Patented J Hanák R biomechanical footwear and insoles are designed to help with redistribution of forces acting on foot, to support both longitudinal and transverse arches of the foot and to strengthen the foot muscles during movement (Gimunová et al., 2017; Hanák & Zvonař, 2013). Experimentally these shoes are given to pregnant women to detection changes of plantar pressure characteristics and foot characteristics during the last trimester. All measurements were done in the same conditions (laboratory, instruments).

Data processing

All parameters were sampled using Novel database pro m (version 25.3.24), which is directly connected with the Emed-xl platform. Data is displayed at the moment of first contact of the foot with the platform to the end of the walk. After collecting all data from pre/post measurements of the experimental and control groups, based on set default scripts, the data was statistically analysed. The first script processed data to these variables (COP characteristics): Centre of pressure index (COPI), a centre of pressure excursion index (COPEI), distance (D) of COP, maximum velocity (MaV) and mean velocity (MeV) of COP. The second script processed data for 10 pre-defined areas of the foot: hindfoot, midfoot, MH1-5 – metatarsal heads, big toe, second toe, toes 3, 4 and 5 (fig. 1) – with these variables: force-time integral (FTI) and contact time (CT). For statistical processing paired t-tests were used (level of statistical significance $p<0.05$). All statistical calculations are mediated by licenced software Novel pro m (version 25.3.24). This software compared each of the variables for both feet of the experimental and the control group within two measurements (the 27th week and the 36th week of pregnancy).

Description of variables:

Center of pressure index (COPI) assesses the ratio between the medial and lateral areas of the foot as determined by the center of pressure. Values of the COPI (> 1) indicate more lateral weight shifting during walking, COPI (< 1) indicates more medial weight shifting during walking (Oeffinger, Pectol & Tylkowski, 2000; Park et al., 2006; Wallace et al., 2018). Center of pressure excursion index (COPEI) assesses the concavity of the center of pressure curve from heel strike to toe-off, and can be a useful parameter in clinical evaluation. Smaller values are associated with more medially directed ground reaction forces which suggest overpronation, while larger values are associated with more laterally directed ground reaction forces, which suggest oversupination (Diaz et al., 2018). Distance (D) evaluates distance the COP traveled during the roll over process (Wallace et al., 2018). Maximum velocity (MaV) is the highest velocity achieved by the COP (Wallace et al., 2018). Mean velocity (MeV) is the mean velocity achieved by the COP (Wallace et al., 2018). Force-time integral (FTI) is a measure of force impulse or the load applied to the plantar region during a certain time (Yihong et al., 2018). Contact time (CT) is an amount of time contact in of the ten pre-defined areas (Wallace et al., 2018).

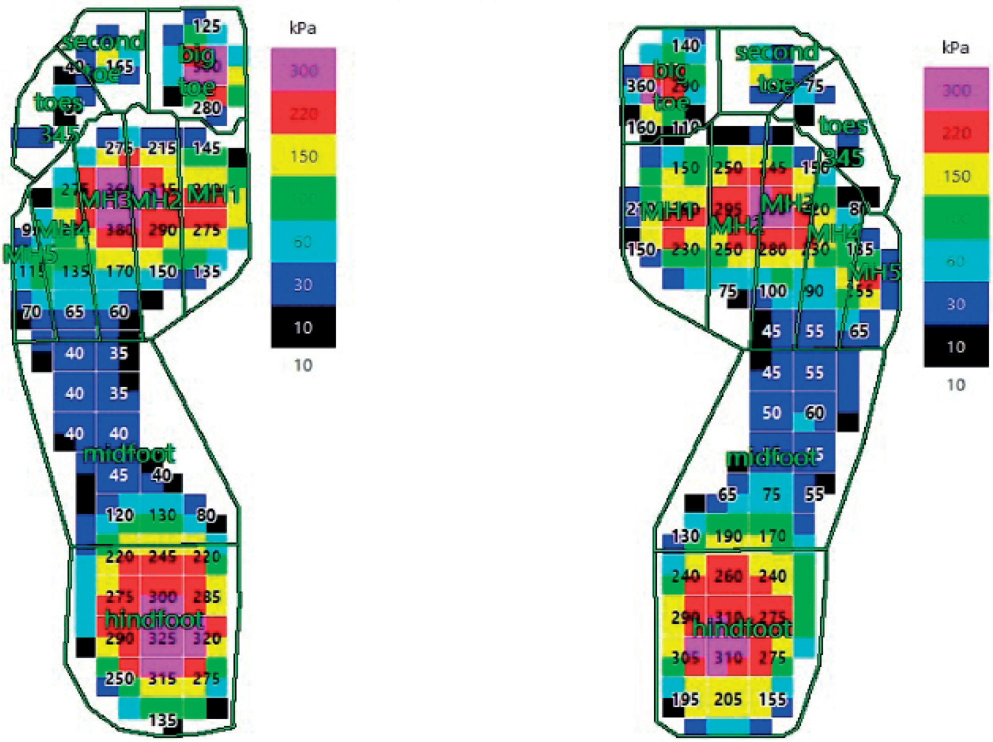

Fig. 1: Ten pre-defined areas of the foot by Novel database pro m (version 25.3.24)

RESULTS

Of 100 participants, 73 pregnant women participated in this study, contributing 365 feet with complete valid Pedobarometry screening on Emed-xl platform.

COP characteristics

The results of COP parameters for the third trimester of pregnancy of both groups are shown in Table 2 and Table 3. For the experimental group, in comparison between 27th week and the 36th week of gestation, we can find lower COPI for both feet, significantly only for the left foot ($p = 0.04$). Also, a significant difference in COPEI ($p = 0.03$, $p = 0.03$) for both feet was found. We can distinctly register extension of D, especially for the left foot ($p = 0.04$). Changes in velocity of COP indicate that MaV was increased for both feet ($p = 0.00$, $p = 0.00$) and MeV was significantly increased only for the right foot ($p = 0.00$) in the 36 week of pregnancy. For the control group, we found no significant changes in COPI, COPEI or COP. MaV and MeV of COP were significantly increased for both feet in the 36 week of pregnancy ($p = 0.02$, $p = 0.00$, $p = 0.01$, $p = 0.00$).

Tab. 2: Comparison of mean COP parameters during the third trimester of the experimental group (n = 35)

Parameters	27 week (L)	27 week (R)	36 week (L)	36 week (R)	*P* (L)	*P* (R)
COPI	1.20 ± 0.15	1.21 ± 0.14	1.17 ± 0.15	1.18 ± 0.13	0.04*	0.06
COPEI (%)	12.74 ± 8.43	14.26 ± 8.33	14.67 ± 8.69	16.05 ± 7.75	0.03*	0.03*
Distance (cm)	22.60 ± 1.35	22.77 ± 1.79	22.91 ± 1.54	23.12 ± 1.51	0.04*	0.06
MaV (m/s)	0.81 ± 0.27	0.79 ± 0.44	0.95 ± 0.38	0.93 ± 0.41	0.00*	0.00*
MeV (m/s)	0.29 ± 0.03	0.28 ± 0.03	0.30 ± 0.03	0.30 ± 0.03	0.06	0.00*

* statistical significance (p < 0.05)
* (L) – left foot
* (R) – right foot

Tab. 3: Comparison of mean COP parameters during the third trimester of the control group (n = 38)

Parameters	27 week (L)	27 week (R)	36 week (L)	36 week (R)	*P* (L)	*P* (R)
COPI	1.18 ± 0.13	1.17 ± 0.14	1.17 ± 0.12	1.15 ± 0.13	0.32	0.14
COPEI (%)	13.34 ± 8.47	14.17 ± 8.323	14.91 ± 8.33	15.52 ± 7.25	0.07	0.09
Distance (cm)	23.12 ± 0.98	23.19 ± 0.79	22.68 ± 0.56	23.15 ± 0.39	0.38	0.91
MaV (m/s)	0.80 ± 0.49	0.70 ± 0.18	0.93 ± 0.64	0.83 ± 0.30	0.02*	0.00*
MeV (m/s)	0.29 ± 0.03	0.28 ± 0.03	0.30 ± 0.04	0.30 ± 0.03	0.01*	0.00*

* statistical significance (p < 0.05)
* (L) – left foot
* (R) – right foot

FORCE-TIME CHARACTERISTICS

In most cases, analysis of the force-time parameters did not reveal significant changes in the comparison of pre/post measurements of the experimental and control group. In comparing the pre/post measurements of the experimental group (Table 4), there is only one significant increase of impulse of force (FTI) in area MH1 of the right foot (p = 0.00). Contact time is significantly lower in areas of MH3 (p = 0.03) and total object (p = 0.00) for the right foot. In comparing the pre/post measurements of the control group (Table 5), we can find an important increase of FTI in the hindfoot (p = 0.03), but paradoxically lower in toes 3, 4 and 5 (p = 0.02) of the right foot. For the left foot, there is a significantly higher impulse of force in areas of MH3 (p = 0.00), MH4 (p = 0.01) and total object (p = 0.00). Significantly shortened contact time is possible to see in toes 3, 4 and 5 (p = 0.02) and total object – whole foot (p = 0.01).

Tab. 4: Comparison of mean force-time parameters for 10 pre-defined areas of the foot during the third trimester of the experimental group (n = 35)

Parameters	27 week (L)	27 week (R)	36 week (L)	36 week (R)	*P* (L)	*P* (R)
Force-time integral (N · s)						
Hindfoot	134.20 ± 38.47	125.70 ± 42.53	138.86 ± 40.98	126.16 ± 37.03	0.27	0.91
Midfoot	36.09 ± 26.04	36.20 ± 24.17	39.34 ± 26.98	36.49 ± 24.44	0.25	0.91
MH1	48.75 ± 24.75	50.64 ± 21.11	50.34 ± 21.48	56.78 ± 22.58	0.52	0.00*
MH2	64.98 ± 21.47	67.01 ± 22.62	68.95 ± 19.74	68.34 ± 19.65	0.07	0.55
MH3	70.10 ± 21.34	71.07 ± 20.42	73.78 ± 20.19	73.03 ± 20.03	0.09	0.36
MH4	45.56 ± 17.75	46.32 ± 17.40	48.98 ± 17.55	46.66 ± 16.16	0.07	0.84
MH5	19.17 ± 11.36	19.41 ± 11.42	19.24 ± 10.55	17.77 ± 8.93	0.95	0.13
Big toe	37.48 ± 17.89	41.97 ± 22.23	36.44 ± 18.93	45.09 ± 24.17	0.59	0.20
Second toe	6.25 ± 3.28	7.53 ± 3.66	5.94 ± 3.36	7.30 ± 3.63	0.38	0.55
Toes 345	5.95 ± 4.34	8.20 ± 6.63	5.33 ± 4.11	7.16 ± 5.98	0.17	0.12
Total object	468.65 ± 96.20	474.17 ± 91.92	487.32 ± 90.26	484.87 ± 86.78	0.06	0.26
Contact time (ms)						
Hindfoot	499.48 ± 88.55	484.34 ± 108.31	496.51 ± 81.55	467.71 ± 90.86	0.74	0.12
Midfoot	497.42 ± 96.98	493.12 ± 108.81	512.80 ± 84.24	481.88 ± 105.16	0.11	0.31
MH1	610.80 ± 79.51	626.74 ± 105.31	621.42 ± 81.21	618.34 ± 79.33	0.21	0.39
MH2	641.08 ± 83.11	656.51 ± 102.48	647.37 ± 76.20	639.14 ± 76.39	0.46	0.07
MH3	660.17 ± 85.71	671.88 ± 98.01	659.88 ± 73.82	652.51 ± 73.45	0.97	0.03*
MH4	654.17 ± 83.97	660.74 ± 105.67	655.60 ± 70.79	642.97 ± 74.41	0.86	0.06
MH5	607.02 ± 87.45	609.60 ± 109.75	609.31 ± 72.96	591.82 ± 79.14	0.79	0.08
Big toe	569.48 ± 108.38	586.51 ± 125.34	574.00 ± 100.99	578.74 ± 103.90	0.68	0.52
Second toe	481.37 ± 114.40	506.68 ± 125.42	470.00 ± 110.69	490.28 ± 106.80	0.34	0.18
Toes 345	471.60 ± 142.92	501.88 ± 170.99	453.54 ± 176.41	472.22 ± 148.65	0.29	0.08
Total object	816.28 ± 91.66	835.02 ± 117.62	801.82 ± 80.83	800.45 ± 79.76	0.11	0.00*

* statistical significance ($p<0.05$)
* (L) – left foot
* (R) – right foot

Tab. 5: Comparison of mean force-time parameters for ten pre-defined areas of the foot during the third trimester of the control group (n=38)

Parameters	27 week (L)	27 week (R)	36 week (L)	36 week (R)	*P* (L)	*P* (R)
Force-time integral (N · s)						
Hindfoot	139.06 ± 33.19	131.38 ± 30.67	145.22 ± 38.44	138.51 ± 35.21	0.09	0.03*
Midfoot	37.95 ± 30.30	35.46 ± 25.63	41.69 ± 30.16	36.06 ± 24.42	0.22	0.81
MH1	43.61 ± 20.20	50.47 ± 23.16	46.18 ± 20.66	53.47 ± 22.02	0.21	0.19
MH2	65.81 ± 17.15	66.06 ± 18.26	69.32 ± 18.41	68.20 ± 17.07	0.06	0.23
MH3	70.81 ± 17.80	68.89 ± 17.24	76.06 ± 18.92	71.77 ± 18.12	0.00*	0.11
MH4	45.49 ± 15.23	43.82 ± 15.18	49.17 ± 15.11	44.97 ± 13.62	0.01*	0.43
MH5	20.14 ± 10.50	19.03 ± 10.14	20.59 ± 9.33	17.97 ± 8.18	0.65	0.26
Big toe	38.99 ± 18.84	46.63 ± 21.35	39.54 ± 23.01	47.21 ± 23.19	0.79	0.80
Second toe	8.04 ± 4.28	8.43 ± 3.47	7.93 ± 5.33	7.94 ± 3.56	0.82	0.17
Toes 345	9.27 ± 7.07	10.30 ± 7.85	8.74 ± 7.91	8.58 ± 7.34	0.49	0.02*
Total object	479.31 ± 75.62	480.66 ± 76.16	504.56 ± 81.63	494.81 ± 77.23	0.00*	0.07
Contact time (ms)						
Hindfoot	516.21 ± 79.72	505.52 ± 72.24	524.31 ± 87.65	495.94 ± 84.71	0.34	0.23
Midfoot	511.78 ± 94.11	501.00 ± 93.44	528.26 ± 81.62	497.47 ± 80.39	0.06	0.69
MH1	615.57 ± 78.03	628.73 ± 80.92	625.68 ± 85.00	624.47 ± 75.04	0.22	0.59
MH2	656.63 ± 74.89	663.00 ± 77.67	660.10 ± 85.08	651.78 ± 72.98	0.67	0.14
MH3	672.94 ± 76.84	676.36 ± 76.24	676.68 ± 81.86	666.10 ± 69.34	0.64	0.17
MH4	669.15 ± 75.20	664.73 ± 74.75	668.84 ± 78.64	652.89 ± 61.79	0.96	0.09
MH5	610.78 ± 74.13	609.94 ± 75.64	620.94 ± 73.53	600.31 ± 56.94	0.18	0.16
Big toe	558.57 ± 119.44	608.00 ± 108.67	560.21 ± 117.58	596.94 ± 107.42	0.89	0.31
Second toe	498.21 ± 94.52	529.05 ± 104.09	493.89 ± 97.81	509.78 ± 101.54	0.66	0.06
Toes 345	520.52 ± 131.30	542.73 ± 128.24	512.42 ± 137.91	513.42 ± 126.81	0.55	0.02*
Total object	843.36 ± 87.44	850.94 ± 92.19	836.26 ± 98.34	826.42 ± 92.99	0.45	0.01*

* statistical significance ($p < 0.05$)
* (L) – left foot
* (R) – right foot

DISCUSSION

Evaluation of COP parameters during the third trimester

In both pregnant groups it is possible to register a COP trajectory deviation what confirmed Mei, Gu a Fernandez (2018) as well. The main evidence of this change is COPI and COPEI which assess COP trajectory in the roll over process of the foot during the stance phase of gait (Diaz et al., 2018). According to Park et al. (2006) and Oeffinge et al. (2000) our values of the COPI (> 1) indicate more lateral weight shifting during the last trimester, as well as lower CPEI values that indicate a more pronated foot during gait, whereas in our case higher CPEI values indicate more supination in comparison pre/post measurement (Galica et al., 2013; Hagedorn et al., 2013). This finding is valid for both groups, but it is statistically significant for the experimental group in comparison of the pre/post measurements. Generally, many published studies indicate that medially shifted COP, thus pronating tendency is observed during pregnancy (Martínez-Martí et al., 2019; Mitternacht, Klement & Lampe, 2013; Vico Pardo et al., 2018). Also, similar studies show that foot pronation is a kinematic effect of gestation. According to Bertuit et al. (2015) and Osman et al. (2002) medio-lateral displacement of reaction forces is higher in late pregnancy. Lymbery et al. (2005) found that mediolateral ground reaction force tended to be increased in a medial direction. The centre of pressure moved more medially during pregnancy. Similarly, Mei et al. (2018) showed a medial shift of COP in the hindfoot area, which could be linked with foot pronation. It is possible that our outcomes were influenced by the use of the specific orthopaedic shoes by the experimental group. So, it could be that wearing these orthopaedic shoes causes changes in COP trajectory so that feet are more in supination during walking. This could bring positive health aspects for legs, because increased pronation of the foot results in internal rotation of the tibia caused by the increased calcaneal eversion angle, which can lead to discomfort, back pain or pain in other parts of the lower extremities during pregnancy (Martínez-Martí et al., 2019; Anselmo, Love, Tango & Robinson, 2017).

The length of COP is changed during the third trimester of pregnancy (Bertuit, Leyh, Rooze & Feipel, 2017), but we can register little difference between groups, where unlike the control group, women wearing orthopaedic shoes showed a tiny extension of COP trajectory, statistically significant only for the left foot (p=0.04). Further, we have registered an increase of MaV and MeV of COP for the experimental group (MaV increase 17%–18%, MeV increase 3%–7% for both feet) and control group (MaV increase 16%–18%, MeV increase 3%–7% for both feet). This finding may indicate that pregnant women increased their preferred velocity of gait. Paradoxically, other authors show that there is a decrease of COP velocity in late pregnancy (Bertuit, Leyh, Rooze & Feipel, 2017; Bertuit, Leyh & Feipel, 2018) and an overall decrease of gait speed (Bertuit, Feipel & Rooze, 2015; Bertuit, Leyh, Rooze & Feipel, 2017; Błaszczyk, Opala-Berdzik & Plewa, 2016). This difference may be due to individual development of biomechanics and physiology in pregnancy, where pregnant women establish very specific and individual gait strategies.

Evaluation of force-time parameters during the third trimester

Based on the evaluation of force-time parameters, we see a similar development of FTI and CT values in almost all cases for both feet. The development trend indicates an increase of FTI values and a decrease of contact time in comparison to pre/post measurements for both feet of both groups. Therefore, the size of the force impulse is probably formed more by force than by time during the gait. Varol et al. (2017) observed a general increase of FTI values during a pregnancy, especially in the midfoot area and this change could be related to increased foot pain.

A decrease of total contact time for both feet of both measured groups in late pregnancy support our COP results that show an increase of MaV and MeV. This opinion supports Ribeiro et al. (2013) who found that increased contact time indicates reduced gait speed. In an older study, Ribeiro et al. (2011) also showed that contact time increased especially at the midfoot and medial and lateral forefoot from the first to the third trimester, but we can't confirm these results in our study. The total decrease of contact time also indicates the decrease of single support, which is observed in many studies (Bertuit, Feipel & Rooze, 2015; Forczek & Staszkiewicz, 2012; Błaszczyk, Opala-Berdzik & Plewa, 2016). On the other hand, Ramachandra et al. (2018) found that there is a single stance duration increase in the third trimester compared to the earlier trimesters.

LIMITATIONS

Our group of healthy pregnant women was measured only during the third trimester, so this study does not include data or analysis of kinematic and kinetic changes during the entire gestation period. Further, this study does not contain kinematic variables (gait velocity, stride length, step length, time of heel strike/toe off) because of cameras for motion caption was not a part of pressure platform for this measurement.

CONCLUSION

Over the last three months of pregnancy, observable significant changes can be found especially through COP parameters for both groups. We found out that specific orthopaedic shoes which were given to the experimental group especially influenced the trajectory of COP, which could have positive health aspects. Further, certain conflicting results in our study in comparison with other similar studies only confirm that individual biomechanics and physiology development in pregnancy affects the kinematic and kinetic aspects of walking differently.

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