

Spatiotemporal Gait Changes During Pregnancy: A Literature Review

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ABSTRACT

Background: Pregnant women experience several changes that can be seen from a spatiotemporal perspective and the parameters are stride length, stride width, walking speed, walking cadence, cycle time, step time. The importance of knowing changes in gait patterns in pregnant women in order to reduce the risk of falling and improve the quality of life of pregnant women. **Purpose:** The purposes of the study were to know the measurement or instrument used as a spatiotemporal parameter, the results of the changes and the factors that influence changes in gait patterns in pregnant women from a spatiotemporal point of view. **Method:** The study using the literature review method by assessing articles with critical appraisal on six articles using JBI's Critical Appraisal. The databases were Google Scholar, National Center for Biotechnology Information (NCBI), PubMed, Science Direct, Garuda Portal, InaBJ with keywords, "pregnancy" OR "pregnant women" OR "pregnant" AND "gait" OR "biomechanics" OR "spatiotemporal". All articles would be organized, remove duplicate articles using EndNote, appraisal, and quality assessment for the risk of bias. **Results:** based on the finding the result from databases, there were 6 articles used for assessment and appraisal. **Conclusion:** increased lumbar lordosis, decreased stride length, decreased walking rhythm, decreased duration of single support, increased duration of double support, increased COP/COG angle were the determinant factors of the spatiotemporal gait changes during pregnancy.

Keywords: pregnancy, spatiotemporal, gait

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INTRODUCTION

Pregnant women experience several changes that could be observed from a spatiotemporal perspective. The alteration including 19% decrease in gait velocity compared to before pregnancy. Furthermore, walking rhythm (cadence) decreases in the second and third trimesters before increase again at 6 months postpartum (Forczek & Staszkiwicz, 2012; Yoo, Shin, & Song, 2015). Meanwhile, pregnant women experienced a decrease in step length and increase in step width when compared to the first trimester; these two significant changes were observed in the second and third trimesters. These changes were also related to changes in the COP (Center of Pressure) or and COG (Center of Gravity) angle of inclination (Krkelj, 2018). The decrease in COP observed in pregnant

women was 16-20%, owing to an increase in step width (Bertuit et al., 2015).

The gait cycle was divided into two phases, the stance phase, and the swing phase. According to (Conder et al., 2019), pregnant women experience decreases in step length and an increase in step width, which will decrease after an initial 8 weeks to the end of 6 months postpartum. According to research conducted by (Forczek et al., 2019), a decrease in stride length and an increase in stride width would be found only in the second and third trimesters.

A decrease in stride length was associated to a low stability index. Meanwhile, pregnant women temporarily experience 19% decrease in walking speed, however several studies suggest that pregnancy had no effect on gait speed unless it was at a high speed (Bertuit, Feipel, & Rooze, 2015).

Due to the changes in posture in pregnant women, COG movement had increased during pregnancy. Meanwhile, the COP angle of pregnant women varies depending on the stage of the gait cycle, with the COP movement decreasing during the forefoot contact phase and increasing during the flatfoot phase (Mei et al., 2018). Several studies have reported that pregnant women exhibit a shorter swing phase and a longer stance phase when compared to non-pregnant women (Aguiar et al., 2015; Bertuit et al., 2017; Błaszczyk, Opala-Berdzik, & Plewa, 2016). Changes in the duration of this stance phase occur during the gestation period and even up to the 8th month postpartum. Furthermore, a study discovered that the duration of the double support phase was longer in pregnant women than in non-pregnant women (Branco et al., 2013). According to research (Błaszczyk et al., 2016), this will return to normal 6-12 months after delivery. Based on the study conducted by (Branco et al., 2013), the duration of the single support phase in pregnant women is shorter than in non-pregnant women. As a result, there was an increase in the duration of the stance phase and the double support phase, as well as an increase in step width, a decrease in the duration of the swing phase and the single support phase, a decrease in stride length, a decrease in rhythm that occurs in pregnant women with ongoing pregnancies when compared to women who do not pregnant. Based on research (Opala-Berdzik et al., 2015) reports that an increase in abdominal mass in pregnant women causes changes in posture, this will affect the stability of walking in pregnant women. Changes in posture are brought on by an increase in the relaxin hormone throughout a continued pregnancy, in addition to an increase in abdominal bulk. Although postural stability in pregnant women tends to rise in the second, third, and six weeks after giving birth, it is still generally stable throughout the first trimester. The percentage of falls during pregnancy is rather significant, reaching 27%, and pregnant women tend to fall 2-3 times higher than non-pregnant people.

This change in the angle of inclination of the COG can be readjusted by making a postural change to the anterior-posterior side. However, this can cause changes in stability in pregnant

women which will affect stability when walking. The instability of pregnant women when walking can increase the risk of falling by 27% with a possibility that is 2-3 times higher than non-pregnant women (Mei, Gu, & Fernandez, 2018). In addition, the measuring instrument used to measure the components of changing road patterns in Indonesia still cannot be carried out optimally. Therefore, researchers want to know the measuring instrument used as a spatiotemporal parameter, the results of the changes and the factors that influence changes in gait patterns in pregnant women from a spatiotemporal point of view.

METHOD

This study uses a literature review method. Articles were obtained from databases, such as Google Scholar, National Center for Biotechnology Information (NCBI), PubMed, Science Direct, Garuda Portal, InaBJ with keywords namely “pregnancy” OR “pregnant women” OR “pregnant” AND “gait” OR “biomechanics” OR “spatiotemporal”. All articles obtained will be continued at the next stage, namely organizing at a later stage, this step is used to remove duplicate articles. Data sources obtained in the form of national and international articles will be filtered based on predetermined criteria, namely: (1) the age of the article respondents is ≥ 21 years, (2) respondents with gestational age starting from 14 weeks (Trimester II and Trimester III), (3) Articles in Indonesian and English with a journal publishing period of 2012-2022 and could be accessed in full text. The results of the literature that have been obtained and meet the requirements; the next step will be a quality assessment that aims to avoid the risk of bias. Researchers use several tools that are used to assess the quality of the article. In the type of cross-sectional study, quasi-experimental, systematic review, cohort study, researchers used a checklist sourced from The Joanna Briggs Institute (JBI) Critical Appraisal Tools. The spatiotemporal parameter itself is a parameter used to measure changes in gait patterns in which there are 6 variables, namely, step length, step width, gait velocity, cadence, step time. step time), cycle time (cycle time).

RESULT

No	Author	Title	Outcome	Confounding factor	Result	JBI Checklist
1	Krkeljas, 2018	Changes in Gait and Posture as Factors of Dynamic Stability during Walking in Pregnancy	Kinematic gait data was recorded with a 3D motion analysis system consisting of eight Oqus 300+ cameras at 220 Hz	The BMI excess pre-pregnancy	There was no significant difference between trimesters in walking kinematics. There was a change in posture, namely trunk hyperextension increased by 112% from T1 to T2 and increased 66% from T2 to T3 ($p \leq 0.001$). Likewise, the angle of inclination of the COP/COG was significantly increased at T3 compared to T1 and T2 ($p \leq 0.001$).	9/11
2	Eldeeb, Hamada, & Abdel-Aziem, 2016	The Relationship Between Trunk and Pelvic Kinematics during Pregnancy Trimester	Gait data was recorded with a 3D motion analysis system consisting of six Pro Reflex cameras and a personal computer.	The appearance of soft tissue artifacts in pelvis in pregnant women caused by an increase in abdominal circumference	There was a significant change between T1 and T2, for cinematic pelvic and trunk, i.e. maximal anterior pelvic tilt during the standing phase ($p=0.005$), i.e. pelvic tilt ($p=0.011$), maximal trunk flexion during the standing phase ($p=0.006$), trunk tilt ($p=0.005$) and trunk rotation ($p=0.002$).	9/11
3	Branco et al., 2013	Kinematic Analysis of Gait in the Second and Third Trimester of Pregnancy	Kinematic data is captured via 10 high-speed infrared cameras at 200Hz and two Kistler force platforms from 0.60m x 0.40m (long wide), at 1000Hz	The difference between the right leg and the left leg in pregnant women	At T2 and T3, there was a significant difference between decreased stride length and double support time which increased each trimester ($=122.342 = 0.000$; power= 0.853). In joint kinematics, a	7/8

No	Author	Title	Outcome	Confounding factor	Result	JBI Checklist
					significant decrease in the first peak of the hip joint was found in the sagittal plane. In addition, there was also a significant decrease in the amount of thigh abduction around 1.4° from T2 to T3.	
4.	Mei, et al., 2018	Alterations of pregnant gait during pregnancy and post-partum	Kinematic data was collected through an eight-camera 3D motion analysis system with a frequency of 200Hz.	Reversible and non-reversible shape change of the feet of pregnant women and non-compliant respondents	there was an increase if compared to T2. The angle of anterior pelvic tilt at T3 was greater when compared to T2 (p=0.013) and PP (p=0.009). The peak external rotation angle of T3 is larger than that of T2 (p=0.034). In addition, there is a lateral shift of ICP during T2 and T3, especially at T3 with a much greater COP than at T2.	7/8
5.	Forczek, et al., 2019	Progressive changes in walking kinematics throughout pregnancy: a follow up study	using a 5-camera video-based motion capture system (120 Hz sampling rate). Subjects were asked to complete the PPAQ to assess physical activity. Assessment of energy balance was assessed using energy intake measurements: weekly food diaries and measurements energy expenditure using the accelerometer	non-compliance of respondents to the rules of measuring instruments and the time of research implementation	on anthropometric measurements there was an increase in body weight, BMI, hip width between trimesters. on spatiotemporal parameter measurements there was no significant change in walking speed, cadence, and stride width. however, on single support duration (SS), inter-ankle distance (IAD), inter-metatarsal distance (IMD), and stride length increased from T1 to T3 (p<0.05). Whereas in the	10/11

No	Author	Title	Outcome	Confounding factor	Result	JBI Checklist
					kinematic data, the hip joint angle increased by 23% during the walking cycle at T3 compared to T2, and the hip elevation was tilted more anteriorly. In addition, when looking at TPA as a whole, physical activity levels tended to decrease during pregnancy (246±74 MET hours/mg on T1 ; 227±76 MET hours/mg on T2 ; 206±84 MET hours/mg at T3)	
6.	Bertuit et al., 2015	Temporal and Spatial Parameters of Gait during Pregnancy	Spatial and temporal parameters of gait were measured using the GAITRite electronic walkway version 3.2b (length: 6.1 m, width: 61 cm) with a frequency of 100 Hz	Less varied respondents	In pregnant women, gait speed, stride length and cadence decreased, cadence reduced 8 to 9% at preferred fast pace (p<0.001) As a result, cycle times became longer, Cycle time increased to 7% at slow pace (p= 0.014), up to 10% at selected speed (p=0.003) and to 9% at fast speed (p=0.031). single observed. Step width increased by 15%.	10/11

DISCUSSION

Based on the result's articles, there were changes occur between trimesters in pregnant women. In the spatially perspective, pregnant women experience several changes, such as an increase in step width about 2 cm (15%) (Bertuit et al., 2015). The increase in step width for everyone would be different because it depends on walking speed. This increase in stride width was closely related to increased external rotation

of the hip (Mei et al., 2018). This step width would decrease by itself (back to normal) after delivery (Bertuit et al., 2015). Based on research conducted by (Mei et al., 2018) suggested that the change in step width could be measured using an eight-camera 3D motion analysis system (VICON Motion System Ltd., Oxford, England).

In addition, the spatial change that occurred was a very significant decrease in stride

length in the 6th month (2nd trimester) and 7th month (3rd trimester) by 13% (Bertuit et al., 2015). This decrease in stride length aims to reduce the risk of falling in pregnant women. This decrease in stride length may be related to the fact that pregnant women experience changes in eye contact with the floor due to abdominal volume (Branco et al., 2013). Based on research conducted by (Forczek et al., 2019) suggests that this change in step width can be measured using a 5-camera video-based motion capture system (120 Hz sampling rate) (Vicon 250; Oxford Metrics Ltd.; Oxford, UK).

Based on temporal perspective, pregnant women experience changes in walking speed that are adjusted to everyone. At the speed determined by the pregnant woman herself (preferred speed), there is a 20% reduction. Whereas at a fast pace there is a decrease of 22% and at a slow speed there is a decrease of 12%. However, this speed will return to pre-pregnancy values with approximately 6 months postpartum, which is to completely reduce a woman's weight. When a pregnant woman walks at her own pace, that's where it needs to be there is an increase in body stability (Branco et al., 2013). Gait speed is highly correlated with increased abdominal mass and increased weight gain in pregnant women, because maximal increase occurs during the third trimester. The increase in body mass that occurs in pregnant women each trimester is 28.4% in Trimester 1, 33.8% in Trimester 2, and 57.2% in Trimester 3 (Krkelj, 2018). Thus, pregnant women reduce walking speed but do not spontaneously choose gait patterns, with the aim of maintaining good stability (Bertuit et al., 2015). Several authors have shown that high stability correlates with slower walking speeds.

In addition, temporarily pregnant women also experience a significant decrease in walking rhythm during late pregnancy by 8-9% (Eldeeb et al., 2016). However, there are studies that report that the rhythm is relatively stable between trimesters of pregnancy (Bertuit et al., 2015). Not only that, but temporarily pregnant women also experience an increase in cycle time of 7-10% and an increase in step time of 8-11% (Bertuit et al., 2015). This temporary change in gait patterns can be measured using the GAITRite electronic walk version 3.2 b (Bertuit et al., 2015).

In one gait cycle consists of 2 phases, namely the stance phase and the swing phase. In pregnant women, there was a decrease in the duration of the swing phase by 2% and an increase in the stance phase by 2%, both changes aim to minimize instability when walking (Bertuit et al., 2015). Several studies have reported that the duration of the swing phase is shorter, and the duration of the stance phase is longer in the final trimester of pregnancy (Aguiar et al., 2015; Bertuit, Leyh, Rooze, & Feipe, 2017; Błaszczuk, Opala-Berdzik, & Plewa, 2016)

During pregnancy the duration of single support during the stance phase decreased significantly from T2 to T3 by 2%, while the duration of double support increased by 5-7% between trimesters of pregnancy ($=122.342$, $=0.000$; power $=0.853$). This increase in the duration of double support between trimesters is related to the fact that pregnant women experience changes in eye contact with the floor due to abdominal volume (Branco et al., 2013). In postpartum conditions, the duration between double support and single support is not significantly different from during pregnancy.

In the gait phase of pregnant women, it is modified by decreasing the swing phase, walking speed, stride length, single support, and increasing the stance phase, double support, and stride width. The purpose of this modification is to support a safer and more stable gait, because pregnant women have a high risk of falling (Mei et al., 2018).

Determinant factors that cause spatiotemporal changes in pregnant women are:

1. Posture changes

Changes in gait and posture during pregnancy cause pregnant women to have a high risk of falling. Pregnant women experience an increase in trunk hyperextension by 61% from Trimester 2 to Trimester 3 (Krkelj, 2018) which will cause an increase in lumbar lordosis. This aims to maintain a stable anterior-posterior CO position (maintaining static balance) despite fetal enlargement. Pregnant women also experience reduced trunk flexion leading to an elongated posture. Postural extension can control COG displacement, thereby reducing the strength of the erector spine muscles to counteract the anterior moment of the abdominal mass. An elongated

trunk will also result in a greater anterior pelvic tilt during movement (Eldeeb et al., 2016).

Pregnant women will make postural adaptations during pregnancy which will cause a shift in the location of the COM from its original position. This results in reduced intersegmental coordination, decreased neuromuscular control and coordination, and changes in biomechanics (gait). Gait changes that occur due to significantly decreased stability due to postural changes that occur during pregnancy, this is closely related to the increase in stride length in pregnant women (Krkelj, 2018).

2. Stability changes

In spatiotemporal changes in pregnant women, especially in step width and stride length, there is a relationship/related to changes in the angle of inclination of the COP/COG (Krkelj, 2018). Based on research (Bertuit et al., 2015) reports that pregnant women tend to experience a decrease in COP (16-20%) that occurs during pregnancy due to an increase in step width. In addition, the increase in step width that occurs in pregnant women is also accompanied by an increase in the distance between the COP and COG (ie, the angle of inclination).

An increase in the angle of inclination of the COP/COG is also largely associated with an increase in the body mass of pregnant women. More than 40% of the variability in the angle of inclination of the COP/COG can be explained by the increase in gestational mass, this occurs because of the postural adjustments while walking during pregnancy (especially at the end of pregnancy, because the increase in body mass is greatest).

Changes in the angle of inclination of the COP/COG that occur in pregnant women seem to increase stability during walking, because an increase in the angle of inclination of the COP/COG is also associated with an increase in margin stability which is thus related to the risk of falling in pregnant women during walking (Hak et al., 2013).

CONCLUSION

There were significant changes that occur in pregnant women which could affect their gait, namely increased lumbar lordosis, decreased stride length, decreased walking rhythm,

decreased duration of single support, increased duration of double support, increased COP/COG angle. While changes that were not significant included an increase in step width, a decrease in physical activity, a decrease in walking speed. The changes that occur are caused by progressive weight gain, lower extremity dysfunction due to an increase in the hormone relaxin, the psyche of pregnant women is related to the fear of falling. As well as the determinant factors in these conditions are changes in posture and changes in stability.

Changes in gait patterns of pregnant women can be measured using an 8-camera 3D analysis system (VICON Motion System Ltd., Oxford, UK), a 5-camera video-based motion capture system (120 Hz sampling rate) (Vicon 250; Oxford Metrics Ltd.; Oxford, UK), and the GAITRite electronic path version 3.2b.

REFERENCES

- Aguiar, L., Santos-Rocha, R., Vieira, F., Branco, M., Andrade, C., & Veloso, A. (2015). Comparison between overweight due to pregnancy and due to added weight to simulate body mass distribution in pregnancy. *Gait Posture*, 42(4), 511-517. doi:10.1016/j.gaitpost.2015.07.065
- Agustini, S. (2017). Pengetahuan Ibu Hamil Tentang Tanda-tanda Bahaya Kehamilan di Wilayah Kerja UPT Puskesmas Cimandala Kecamatan Sukaraja Kabupaten Bogor *FKM UI*.
- Bertuit, J., Feipel, V., & Rooze, M. (2015). Temporal and spatial parameters of gait during pregnancy. *Acta Bioeng Biomech*, 17(2), 93-101.
- Bertuit, J., Leyh, C., Rooze, M., & Feipe, V. (2017). Pregnancy-related changes in center of pressure during gait. *Acta Bioeng Biomech*, 19(4), 95-102.
- Błaszczuk, J. W., Opala-Berdzik, A., & Plewa, M. (2016). Adaptive changes in spatiotemporal gait characteristics in women during pregnancy. *Gait Posture*,

- 43, 160-164.
doi:10.1016/j.gaitpost.2015.09.016
- Branco, M., Santos-Rocha, R., Aguiar, L., Vieira, F., & Veloso, A. (2013). Kinematic analysis of gait in the second and third trimesters of pregnancy. *J Pregnancy*, 2013, 718095. doi:10.1155/2013/718095
- Eldeeb, A. M., Hamada, H. A., & Abdel-Aziem, A. A. (2016). The relationship between trunk and pelvis kinematics during pregnancy trimesters. *Acta Bioeng Biomech*, 18(4), 79-85.
- Forczek, W., Ivanenko, Y., Curyło, M., Frączek, B., Masłoń, A., Salamaga, M., & Suder, A. (2019). Progressive changes in walking kinematics throughout pregnancy-A follow up study. *Gait Posture*, 68, 518-524. doi:10.1016/j.gaitpost.2019.01.004
- Forczek, W., & Staszkiwicz, R. (2012). Changes of kinematic gait parameters due to pregnancy. *Acta Bioeng Biomech*, 14(4), 113-119.
- Hak, L., Houdijk, H., Steenbrink, F., Mert, A., van der Wurff, P., Beek, P. J., & van Dieën, J. H. (2013). Stepping strategies for regulating gait adaptability and stability. *J Biomech*, 46(5), 905-911. doi:10.1016/j.jbiomech.2012.12.017
- Krkeljas, Z. (2018). Changes in gait and posture as factors of dynamic stability during walking in pregnancy. *Hum Mov Sci*, 58, 315-320. doi:10.1016/j.humov.2017.12.011
- Mei, Q., Gu, Y., & Fernandez, J. (2018). Alterations of Pregnant Gait during Pregnancy and Post- Partum. *Sci Rep*, 8(1), 2217. doi:10.1038/s41598-018-20648-y
- Widatiningsih, S., & Dewi, C. H. T. (2017). Praktik terbaik asuhan kehamilan. *Yogyakarta: Trans Medika*.
- Yoo, H., Shin, D., & Song, C. (2015). Changes in the spinal curvature, degree of pain, balance ability, and gait ability according to pregnancy period in pregnant and nonpregnant women. *J Phys Ther Sci*, 27(1), 279-284. doi:10.1589/jpts.27.279