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Comparison between overweight due to pregnancy and due to added weight to simulate body mass distribution in pregnancy

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ABSTRACT

The assessment of biomechanical loading in the musculoskeletal system of the pregnant women is particularly interesting since they are subject to morphological, physiological and hormonal changes, which may lead to adaptations in gait. The purpose of this study was to analyze the effect of the increased mass in the trunk associated to pregnancy on the lower limb and pelvis, during walking, on temporal-distance parameters, joint range of motion and moments of force, by comparing a pregnant women group to a non-pregnant group, and to this group while carrying a 5 kg additional load located in the abdomen and breasts during walking, to understand which gait adaptations may be more related with the increased trunk mass, or if may be more associated with other factors such as the girth of the thigh. The subjects performed a previous 12 min training adaption to the added load. To calculate ankle, knee and hip joint angles and moments of force, a three-dimensional biomechanical model was developed. The inverse dynamics method was used to estimate net joint moments of force. The increased mass of the anterior trunk associated with second trimester of pregnancy may influence some gait variables such as the left step time, left and right stance times, double limb support time, maximum hip extension, maximum pelvic right obliquity, pelvic obliquity range of motion, maximum transversal left rotation and peak hip flexion moments of force.

1. Introduction

During pregnancy, women are subject to morphological, physiological and hormonal changes, which can lead to adaptations in gait. These changes include weight gain [1,2], extended lower back [3], increased ligamentous laxity [4], decreased neuromuscular control and coordination [5,6], swelling of the arms and legs [7], altered biomechanical parameters such as changes in mechanical loading and joint kinetics [8–10], decreased of abdominal muscle strength [11] and increased spinal lordosis [2]. Also, more than 50% of the women reported swelling of the foot, ankle, and leg, unsteady gait, increased foot width and hip pain [12].

The recommendations for body mass increase of a woman with a normal pre-pregnancy body mass index (BMI) are, on average, between 11.5 and 16 kg, and its distribution depends on different components as the fetus growth, placenta, amniotic fluid, uterus, mammary gland, blood and adipose tissue [13].

While walking on the treadmill, it was found that in pregnancy self-selected velocity was significantly lower, while pelvis and thorax rotation amplitudes were slightly reduced [6]. Gilleard found that sagittal plane range of motion for thoracic, pelvic and thoracolumbar spine and walking velocity, showed no linear trends with advancing pregnancy. In post-birth, the thoracic segment range of motion increase and pelvic range of motion decrease in comparison to late pregnancy [14].

Foti et al. [8] reported an increase in the following variables: stride width, hip moment of force (Mf), power in the frontal and sagittal planes, maximum ankle plantar flexion Mf, and maximum ankle plantar flexion power absorption, use of the abductor and extensor muscles of the thigh and in the use of the ankle plantar flexor muscles.

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The increased use of hip muscles may contribute to the pain in lower back, pelvic and hip. Stride width increase results in a larger base of support during walking, probably to improve locomotor stability [8,15].

When comparing the effect of externally distributed load carriage with the influence of excessive body mass, a greater hip range of motion (ROM) was found in the former [16].

The purpose of this study was to understand which gait adaptations may be related with an increased trunk mass or more associated with other factors such as the girth of the thigh during pregnancy. We have assessed the temporal-distance parameters, joint ROM and Mf of the lower limb and pelvis during walking and compared three groups: pregnant, non-pregnant and non-pregnant women carrying a 5 kg additional load located in the abdomen and breasts during walking. This study is an alternative to those that use a longitudinal approach to characterize the gait changes along pregnancy [8,17].

2. Methods

The study was approved by the ethics committee of FMH – University of Lisbon. All women gave informed consent to participate voluntarily in the study.

The sample consisted of two groups:

(1) Eighteen pregnant women, twelve primiparas and six multiparas, with 27.3 ± 3 weeks of gestational age (second trimester), mean age of 32.6 ± 2.7 years, body mass of 68.2 ± 7.3 kg, height of 1.60 ± 0.1 m and BMI of 26.3 ± 2.6 kg/m^2 and 98.5 cm of abdominal girth.
(2) Eighteen non-pregnant women with mean age of 20.4 ± 1.5 years, body mass of 58.9 ± 8.4 kg, height 1.60 ± 0.1 m and BMI of 21.9 ± 2.7 kg/m^2.

An extra load was added in the abdomen and breasts of the non-pregnant women, providing a representation of this condition and taking into account only this anthropometric characteristic.

A strong large strap adjustable to the abdominal area was constructed in order to load sandbags with 0.5, 1 and 2 kg of mass. The sand allowed adjusting the volume of the extra load to the morphological characteristics of each subject, being tight at the waist with Velcro®.

The non-pregnant group (NPG) performed unloaded and loaded barefoot walking. The load was calculated based on Institute of Medicine recommendations for mass gain during pregnancy [13], which was 0.42 kg/week; we assumed that the mass distribution was 34.3% located in the lower trunk [18] resulting in 4 kg and 0.5 kg in each breast, which value was based on [19] and in the mass distribution for the upper trunk [18]. In this condition the group was called load carrying (LCG), with average values of 64.5 kg of mass, 24 kg/m^2 of BMI and 92.6 cm of abdominal girth.

Reflective spherical markers were placed on anatomical landmarks according to the defined marker setup protocol suggested by Capozzo et al. [20].

Motion capture was performed with an optoelectronic system of twelve cameras Qualisys (Oqus-300) at a frame rate of 200 Hz, synchronized with two force platforms (Kistler AG, Winterthur, Switzerland) and one AMTI (Advanced Mechanical Technology, Inc., Watertown, MA), to collect ground reaction force data. The participants performed three 1-min trials of barefoot walking at a self-selected velocity, with a break of 30 s between each trial, making a total of approximately 20 cycles and the best 5 were selected for analysis. The subjects were not informed about the platforms location.

For load adaptation, the NPG performed a 12 min predefined route with walking and climbing/descending stairs, before data collection.

To reduce noise, the motion data were filtered, using a low pass Butterworth filter, with a cutoff frequency of 15 Hz [21].

A global optimization on the data processing algorithm was performed [22] to reduce the effect of soft tissue artifact. The model assumed a universal joint to the ankle, a revolute joint to the knee and a spherical joint to the hip.

The inverse dynamics method was used to estimate net joint Mf. To calculate ankle, knee and hip joint angles and Mf, the three-dimensional biomechanical models were developed with the software Visual 3D C-Motion, Inc. The weights and locations of the centers of mass for each body segments of the NPG were calculated using the regression equations of Dempster and inertia moments using inertial properties based on their shape [23]. For LCG we added 4 kg on the pelvis mass. For pregnant group (PG) we used relative masses proposed by Jensen [18]. The foot segment was defined by the first and fifth metatarsals, lateral and medial tibia malleolus. The zero ankle angle (neutral position) is approximately 70°, but not changing the ankle ROM.

The results were based on five representative cycles per subject, selected based on the stability of gait. Both angular displacement and Mf data were normalized to time cycle, and Mf was normalized to body mass.

For descriptive statistics, continuous data are presented as mean and standard deviations. For the variables with normal distribution (Shapiro–Wilk test), the comparison between NPG and PG were performed using the Student *t*-test. The Mann–Whitney *U*-test was used when normal distribution was not verified. The comparisons between the NPG and LCG, were carried out by paired-samples *t*-test and the Wilcoxon non-parametric test. Statistical tests were performed using PAWS-19. A $p < 0.05$ was used to denote statistical significance.

3. Results

Concerning the temporal distance parameters (Table 1), right and left stance phase (SP) time, and double limb support time (DLST), PG had higher values when compared to NPG. The right SP represented 60.2% and 59.6% of the gait cycle on PG and NPG, respectively. The left step time increased in PG. Stride width was wider in PG.

Table 1
Comparison of temporal distance parameters mean and standard deviation between groups (1) non-pregnant group (NPG) and pregnant group (PG), (2) NPG and load carrying group (LCG) and (1, 2) PG and LCG.

Variable	NPG	PG	LCG	*p* value
Velocity (m/s)	1.24 ± 0.13	1.16 ± 0.12	1.19 ± 0.16	NPG_LCG) <0.001[b]
Stride width (m)	0.08 ± 0.02	0.10 ± 0.02	0.08 ± 0.02	NPG_PG) 0.025[a] PG_LCG) 0.040[a]
Left step length (m)	0.64 ± 0.06	0.62 ± 0.05	0.63 ± 0.06	NPG_LCG) 0.001[a]
Right step length (m)	0.65 ± 0.06	0.62 ± 0.05	0.63 ± 0.07	NPG_LCG) <0.001[b]
Left step time (s)	0.52 ± 0.02	0.54 ± 0.03	0.53 ± 0.03	NPG_PG) 0.036[a] NPG_LCG) 0.023[a]
Left stance time (s)	0.62 ± 0.04	0.65 ± 0.04	0.64 ± 0.05	NPG_PG) 0.030[a] NPG_LCG) 0.006[a]
Right stance time (s)	0.62 ± 0.03	0.65 ± 0.04	0.63 ± 0.05	NPG_PG) 0.005[a] NPG_LCG) 0.006[a]
Double limb support time (s)	0.19 ± 0.03	0.22 ± 0.03	0.21 ± 0.03	NPG_PG) 0.002[a] NPG_LCG) <0.001[b]

[a] A significant difference (level of significance $p < 0.05$).
[b] A significant difference (level of significance $p < 0.001$).