



Effects of transporting an infant on the posture of women during walking and standing still



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ABSTRACT

We investigated the effects on women of carrying an infant in front, focusing on the pelvic and spinal posture and the displacement of the body's center of gravity. For such, we compared mothers to non-mothers not carrying anything or carrying the same load (a doll) and the mothers carrying their infants. Twenty mothers and 44 women who did not have children were analyzed for their movement and posture during walking and standing still with a motion capture system. Walking while carrying a load was slower and with a shorter stride length than while not carrying a load. The mothers' group walked slower and with a shorter stride length than the non-mothers' group. During walking and standing still, the women decreased their angle of pelvic anteversion, increased lumbar lordosis, increased thoracic kyphosis, and increased trunk backward inclination while carrying a load in comparison with not carrying anything. In addition, we observed some small differences in the spinal angles of mothers when carrying their infants compared to when carrying a doll. When standing still, the women carrying a load displaced backwards their vertical projection of the center of gravity to exactly compensate the destabilizing load at the front that resulted in no net change of the body-plus-load center of gravity. In general, these changes are qualitatively similar to the ones observed during pregnancy.

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1. Introduction

Carrying an infant literally places humankind's future in the hands of the mothers. This task, in fact, begins months before for the pregnant woman and it is associated with large changes in her body weight and her body posture as the fetus develops. During pregnancy, there are indications of progressive increases of the thoracic and lumbar curvatures, pelvic anteversion, and trunk extension [1–6]. These changes in body posture are thought to be biomechanical adaptations for maintaining balance with the new body weight distribution. Accompanying these biomechanical changes, pregnant women frequently experience pelvic and back pain, particularly in the lumbar region, and for many of the

mothers, this complaint will persist or begin in the postpartum period when carrying their infants [7–10].

Carrying the infant in front with the arms may impose similar physiological and biomechanical demands on the mother as during the pregnancy. Although the infant is not constantly held, this new task will typically persist for more than nine months. The mechanical load would presumably be higher due to the infant's increased weight and the mother's increased lever arm in the sagittal plane with the infant in her arms. Therefore, similar posture alterations observed during pregnancy are expected when carrying an infant in front with the arms; however, this assertion is yet to be verified. Surprisingly, no study so far has quantified the actual changes on the posture of the mother carrying her infant with the arms during typical movements of daily life, such as walking or standing upright. The few known studies on this topic had a different focus. In the past, carrying an infant might have been a selective pressure that led to the evolution of bipedalism in ancestral hominids [11–14]. Studies were focused on the physiological cost of walking while carrying an infant [11,12], on mechanical analyses of infant-carrying in hominoids that have

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fur, for infant clinging [13], and on the effects of pregnancy on body posture [14]. A limitation of the studies investigating women is the fact that none investigated mothers carrying their own infants. For methodological reasons, they analyzed women carrying dummy infants, instead [11,12].

In view of that, the main goal of this study is to investigate the effects on the mother when she carries an infant in front, focusing on the pelvic and spinal posture and the displacement of the body's center of gravity during walking and standing still. For such, we compared mothers to non-mothers carrying nothing or carrying the same load (a doll) and the mothers carrying their infants versus carrying a doll. We hypothesize that: (1) Carrying a load (doll or infant) will affect the pelvic and spinal posture and the displacement of the body's center of gravity of both mothers and non-mothers. (2) Mothers carrying their infants will have a different effect than carrying a doll.

2. Methods

2.1. Subjects

Twenty mothers (mother's group) and 44 nulligravida women (non-mother's group), all without any current musculoskeletal problems, participated in this study. Fifteen mothers were primigravida (pregnant for the first time) and 18 of them gave birth by cesarean section. We selected mothers with children of approximately 10 kg weight who were one-year old. As a result, the mean (± 1 standard deviation, SD) mass of the children was 9.9 ± 1.1 kg with a mean ± 1 SD age of 11 ± 5 months old. The mean ± 1 SD age, mass, height, and body-mass index of the mothers were 31 ± 5 years old, 61 ± 12 kg, 1.63 ± 0.07 m, and 22.9 ± 5.0 kg/m², respectively. For the non-mother's group, the mean ± 1 SD age, mass, height, and body-mass index of the mothers were 29 ± 3 years old, 59 ± 7 kg, 1.66 ± 0.08 m, and 21.4 ± 2.0 kg/m², respectively. There was no between-group difference with respect to these characteristics. All participants signed an informed consent form approved by the local ethics committee, and the experimental procedure was conducted in accordance with the Declaration of Helsinki.

2.2. Tasks and instrumentation

The women were asked to complete two tasks: (1) walking straight for 10 m on a level floor at a comfortable speed, and (2) quiet upright standing for 30 s. For both tasks, there were three conditions for the mother's group: (a) carrying nothing (no load), (b) carrying her infant (infant), and (c) carrying a doll with the same weight as her infant (doll). We used a realistic, 50 cm-tall baby doll made of vinyl and wearing a bodysuit; see the supplementary material for a picture of a mother carrying the doll. The non-mother's group performed only the no-load and doll (with 10 kg) conditions. The order of conditions was randomly selected for each woman. We instructed the mothers to carry the infant or doll always at the front of the trunk with both arms. The women performed 10 trials of walking for each condition and only one trial of standing still. Once a walking speed was adopted by the woman at each load condition, she was instructed to walk at that speed at all trials. None of the infants was sleeping during data collection; the mothers tried to calm their infants, but we observed spontaneous movements by the infants during some of the trials.

For the kinematic description of the segmental displacements during the tasks, we employed a marker set and model [15] which allows the calculation of 2D projection angles based on three points for each region and plane of interest (see Fig. 1). Accordingly, reflective markers were placed on the seventh spinous vertebral process (C7), apex of kyphosis (T6 or T7, depending on the woman), apex of lordosis (L3), lower edge of sacrum (S2 or S3), and left and right posterior superior iliac spines (PSIS). In addition, we placed markers on the left and right sides of the anterior superior iliac spines (ASIS) and heels at the feet. The only difference in relation to the model from the literature [15] was that we defined a reference frame for the pelvis (the local frame) based on the PSIS and ASIS markers [16]. This evaluation was performed using a 3D movement analysis system (Vicon 460 with six M2 cameras, Oxford Metrics, UK) operating at 60 Hz and two force plates (OR6-7-2000, AMTI, Inc., USA) embedded in the middle of the 12 m-long floor operating at 120 Hz to measure the ground reaction forces. For the standing still task, the women stood on one force plate as still as possible for 30 s in each condition.

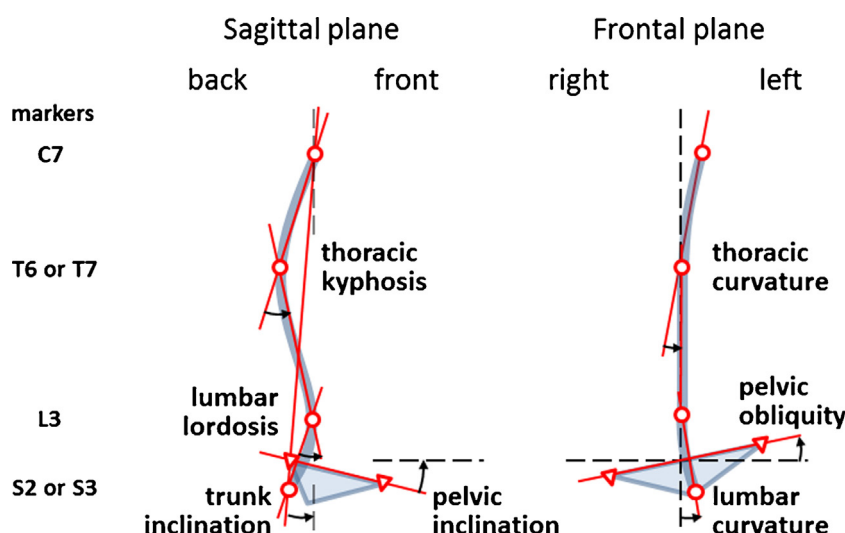


Fig. 1. Marker placement and angle convention adopted for the measurement of the spinal and pelvic angles [15]. Four markers on the pelvis (triangles in the figure) were placed on the left and right posterior and anterior superior iliac spines. The pelvic rotation angle (not shown) occurs at the transverse plane and is positive when the left foot is in front.

2.3. Data analysis

All the kinematic data were smoothed with a low-pass Butterworth filter with a 10 Hz cut-off frequency, fourth-order, and zero-lag. The ground reaction forces were smoothed with a similar filter but using 100-Hz cutoff frequency. For the walking task, we calculated the spatiotemporal variables: stride length and walking speed; the angles of the pelvis: inclination (anteversion/retroversion), obliquity, and rotation; and the angles of the spine: thoracic kyphosis, lumbar lordosis, trunk inclination (extension/flexion), and thoracic and lumbar curvatures of the spine in the frontal plane (related to scoliosis). For each trial, we analyzed one stride cycle defined as the events between two successive strikes of the right foot on the floor. Each woman performed four to six steps before and after the analyzed stride cycle. Each time series of these angles for the gait cycles was normalized in time from 0% to 100% in steps of 1%. These cycles were averaged across trials to obtain the mean cycle for each woman and the same process was repeated to obtain the mean and SD cycle among women. We analyzed the mean, minimum, maximum, and range of motion values of each angle across the whole time series for the walking task and the mean values for the standing still task. The results for all variables are presented in the supplementary material; only the results for the mean angle are presented in this text.

For the standing still task, we calculated the same angles reported previously, and to describe any change in posture of the lower limbs, we calculated the angle of the segment defined by the markers on the heels and sacrum with respect to the vertical. To quantify the mean body position, we estimated the position of the vertical projection (in the horizontal plane) of the body's center of gravity (COGv) based on the force plate center of pressure displacement employing the zero-point-to-zero-point double integration technique [17]. This technique produces similar results to the kinematic method based on the positions of the segments of the whole body, but it is simpler to measure [18]. We calculated the mean displacement in the anterior–posterior (AP) and mediolateral (ML) directions of the COGv in relation to the mean position of the subject's heels. Positive values mean that the COGv AP and ML are displaced respectively forward and to the right in relation to the mean position of the heels.

All the calculations were performed using custom programming implemented in Visual3D (C-Motion, Inc., USA) and Matlab (Mathworks, Inc., USA) software. To determine the effects of the factor's group (non-mothers and mothers) and load condition (no load and doll), we employed a 2×2 mixed Anova on each dependent variable and *t*-tests with Bonferroni correction for multiple comparisons as post hoc. To determine the effect of carrying the infant versus not carrying a load or carrying a doll, for the Mother's group we employed a one-way repeated-measures ANOVA on each dependent variable and *t*-tests with Bonferroni correction for multiple comparisons as post hoc. As measures of effect size, we computed the generalized eta-squared (η^2) for the

ANOVA and Cohen's *d* for the *t*-tests. The significance level adopted for all statistical tests was 0.05. The statistical analysis was performed using the R software (<http://www.r-project.org/>). For the standing still task, data derived from two subjects in the mother's group were lost and not used in the analyses.

3. Results

Walking carrying a doll was slower ($F(1,62) = 38$, $p < 0.001$, $\eta^2 = 0.03$) with shorter stride length ($F(1,62) = 75$, $p < 0.001$, $\eta^2 = 0.06$) than not carrying a doll for both groups. The mothers walked slower ($F = 10.3$, $p = 0.002$, $\eta^2 = 0.14$) with shorter stride length ($F = 17.4$, $p < 0.001$, $\eta^2 = 0.21$) than the non-mothers. The mothers walked slower ($p = 0.04$, $d = 0.22$) with shorter stride length ($p < 0.001$, $d = 0.52$) when carrying their infant than not carrying anything. See Table 1 for mean $\pm$ 1SD values and the supplementary material for interaction plots.

Both groups of non-mothers and mothers exhibited consistent patterns for all pelvic and spinal angles across the various walking and standing still conditions (see Figs. 2 and 3 and Tables 2 and 3). The mean within-subject variability across the gait cycle was similar for all the measured angles and was on average $1.1 \pm 0.4^\circ$. The between-subject variability across the gait cycle and across angles was $4.0 \pm 1.7^\circ$. The pelvic inclination, thoracic kyphosis, and lumbar lordosis angles presented between-subject variability about two times greater than the other measured angles. These values were similar among groups and conditions.

Women carrying a doll during walking (W) and standing still (S) decreased the mean angle of pelvic inclination (W: $F = 86$, $p < 0.001$, $\eta^2 = 0.03$ and S: $F = 116$, $p < 0.001$, $\eta^2 = 0.13$) and increased the mean angles of lumbar lordosis (W: $F = 190$, $p < 0.001$, $\eta^2 = 0.17$ and S: $F = 18$, $p < 0.001$, $\eta^2 = 0.03$), thoracic kyphosis (W: $F = 52$, $p < 0.001$, $\eta^2 = 0.07$ and S: $F = 15$, $p = 0.001$, $\eta^2 = 0.04$), and trunk backward inclination (W: $F = 867$, $p < 0.001$, $\eta^2 = 0.72$ and S: $F = 540$, $p < 0.001$, $\eta^2 = 0.65$) in comparison with not carrying anything. Likewise, mothers carrying their infant during walking and standing still decreased the mean angles of pelvic inclination (W: $p = 0.02$, $d = 0.32$ and S: $p = 0.02$, $d = 0.59$) and increased the mean angles of lumbar lordosis (only for W: $p < 0.001$, $d = 1.3$), thoracic kyphosis (W: $p = 0.03$, $d = 0.30$ and S: $p < 0.001$, $d = 0.57$), and trunk backward inclination (W: $p < 0.001$, $d = 0.57$ and S: $p < 0.001$, $d = 2.9$) in comparison with not carrying anything. For the comparison of the infant and doll conditions during walking and standing still, the mothers increased the mean angles of lumbar lordosis (only for W: $p < 0.001$, $d = 0.23$) and trunk inclination (W: $p < 0.001$, $d = 0.65$ and S: $p = 0.004$, $d = 0.69$) and decreased thoracic kyphosis (only for W: $p = 0.009$, $d = 0.19$) when carrying the infant.

There were no other statistically significant effects for any of the mean values of the other angles for walking or standing still. Particularly, during standing still there was no change in the mean angle of the lower limbs with respect to the vertical, which indicates that the changes in the body posture were restricted to the upper body. For the range of motion and minimum and maximum values of the measured angles (results shown in the supplementary material), there was a decrease in range of motion for the thoracic curvature. Related to the changes in the mean values of the angles reported in the previous paragraph, there were corresponding changes in the minimum and maximum values. There were no statistically significant effects for the COGv displacements during standing still (see Table 1 for mean $\pm$ 1SD values).

4. Discussion

We investigated the effects of carrying an infant on the mother's posture, comparing mothers to non-mothers not carrying anything or carrying the same load (a doll) and the mothers carrying their infants versus carrying a doll. We confirmed our first hypothesis: carrying a load (doll or infant) affects the posture of both mothers and non-mothers; and partially the second hypothesis: there were

Table 1

Mean $\pm$ 1SD values across subjects at each condition of the stride length and walking speed during walking, and of the center of gravity position of the subject's body plus load (COGv) in relation to the mean position of the heels at the anterior–posterior (AP) and mediolateral (ML) directions during standing still.

Variable	Task	Group				
		Non-mothers		Mothers		
		No load	Doll	No load	Doll	Infant
Stride length (m)	Walking	1.29 $\pm$ 0.09 ^{G, C}	1.24 $\pm$ 0.09 ^{G, C}	1.19 $\pm$ 0.09 ^{G, C, NI}	1.14 $\pm$ 0.10 ^{G, C}	1.15 $\pm$ 0.08 ^{NI}
Speed (m/s)	Walking	1.21 $\pm$ 0.15 ^{G, C}	1.16 $\pm$ 0.15 ^{G, C}	1.08 $\pm$ 0.18 ^{G, C}	1.02 $\pm$ 0.21 ^{G, C}	1.04 $\pm$ 0.18
COGv AP (cm)	Standing	9.8 $\pm$ 1.1	9.6 $\pm$ 1.1	9.4 $\pm$ 1.1	9.6 $\pm$ 1.7	9.8 $\pm$ 1.6
COGv ML (cm)	Standing	−0.4 $\pm$ 0.8	−0.5 $\pm$ 0.9	−0.3 $\pm$ 0.7	−0.4 $\pm$ 0.9	−0.2 $\pm$ 0.8

The superscripts indicate significant main effects of group (G) and condition (C) and significant differences between infant and no-load (NI) or doll (DI) conditions for the mothers.

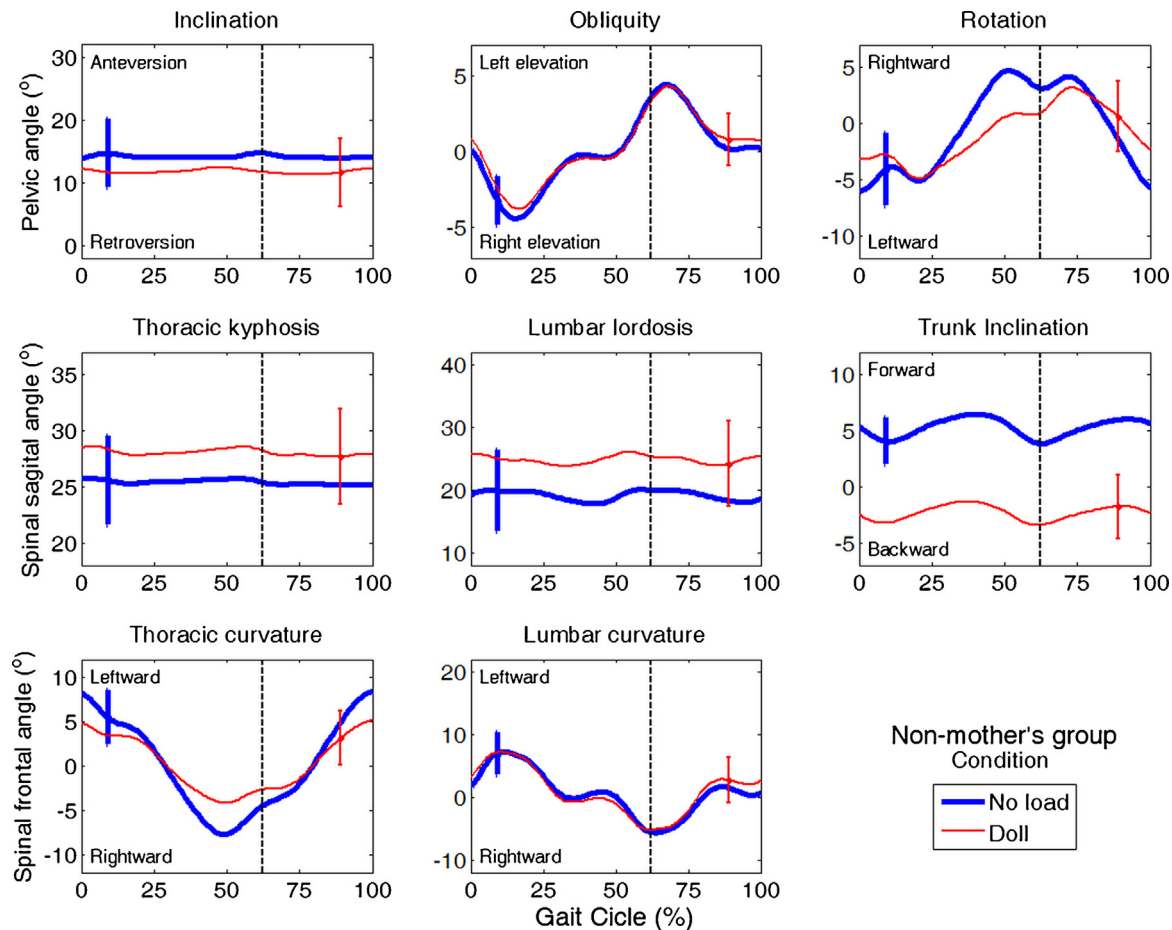


Fig. 2. Mean time series across subjects at each condition of the pelvic and spinal angles during one stride cycle (starting with the right foot) of walking for the non-mother's group. For sake of clarity, the mean curve and only one ± 1 standard deviation vertical bar are shown for each condition. The dashed vertical line denotes the end of the support phase.

some small differences in the spinal angles of the mothers carrying their infants compared to when carrying a doll. Next, we discuss these findings in detail.

When asked to walk at comfortable speeds carrying a load, either a doll or an infant, mothers and non-mothers walked slower and with shorter strides than when not carrying anything (and the mothers were always slower than the non-mothers). A decrease in stride length but not in walking speed has been observed in a longitudinal study of pregnant women, i.e., an incremental decrease of stride length with the development of the fetus [19]. Decreases in both stride length and speed have been observed for women carrying inanimate loads in studies on the energetic costs of infant carrying [11,12]. In agreement with those latter studies, we interpret the observed decreases in speed and stride length as an adaptive response to the higher energetic demand of the load-carrying task due to the increased mass. (For carrying an infant, this would represent a 10–20% increase in the total mass). However, in an evolutionary context, the decision to carry the infant would not necessarily be influenced by instantaneous energetics. It would also be influenced by the potential to enhance the mother's future reproductive success; energetically unfavorable carrying would occur in situations where speed or safety is important [11].

Concerning the body posture during walking, carrying a load symmetrically in the front of the trunk with both arms, either a doll or an infant, affects only the posture in the sagittal plane of mothers and non-mothers. This change in posture consists mainly of a decrease in the mean angles across the gait cycle of the pelvic

anteversion (i.e., with a load, the women tilted backwards their pelvis), and increases in the mean angles of thoracic kyphosis, lumbar lordosis, and trunk backward inclination. A decrease in the pelvic anteversion is the opposite of what is generally observed in pregnant women during walking [1], although a significant change has not been observed in pregnant women when standing still [5,20]. However, the values of the pelvic anteversion were very variable across subjects, which was also observed in [1]. For the spinal angles at the sagittal plane, similar changes have been observed in pregnant women [1–6] and for the thoracic kyphosis and lumbar lordosis angles of women when the effect of breast size was investigated [20]. Furthermore, in agreement with these studies about pregnant women and women with larger breast sizes, we observed that most of the change occurs at the lumbar spine rather than at the thoracic region. This latter finding was also observed in a study about the role of the woman's lumbar lordosis to adapt to the fetal load [14]. Interestingly, according to this last article, the pattern of lumbar lordosis and its degree of mobility to adapt to such mechanical demands are unique to women (sexual dimorphism). This pattern already exists in *A. afarensis*, a biped fossil estimated to have lived 3.2 million years ago, and possibly had an important role in the adoption of bipedalism by humans. The present results suggest that not only the fetal load but likely also the infant carrying acted as a selective pressure in favor of the lumbar lordosis, particularly when the body fur was reducing in early hominid evolution [13].

Regarding the variability of the pelvic and spinal angular movement when walking, each woman was consistent across the

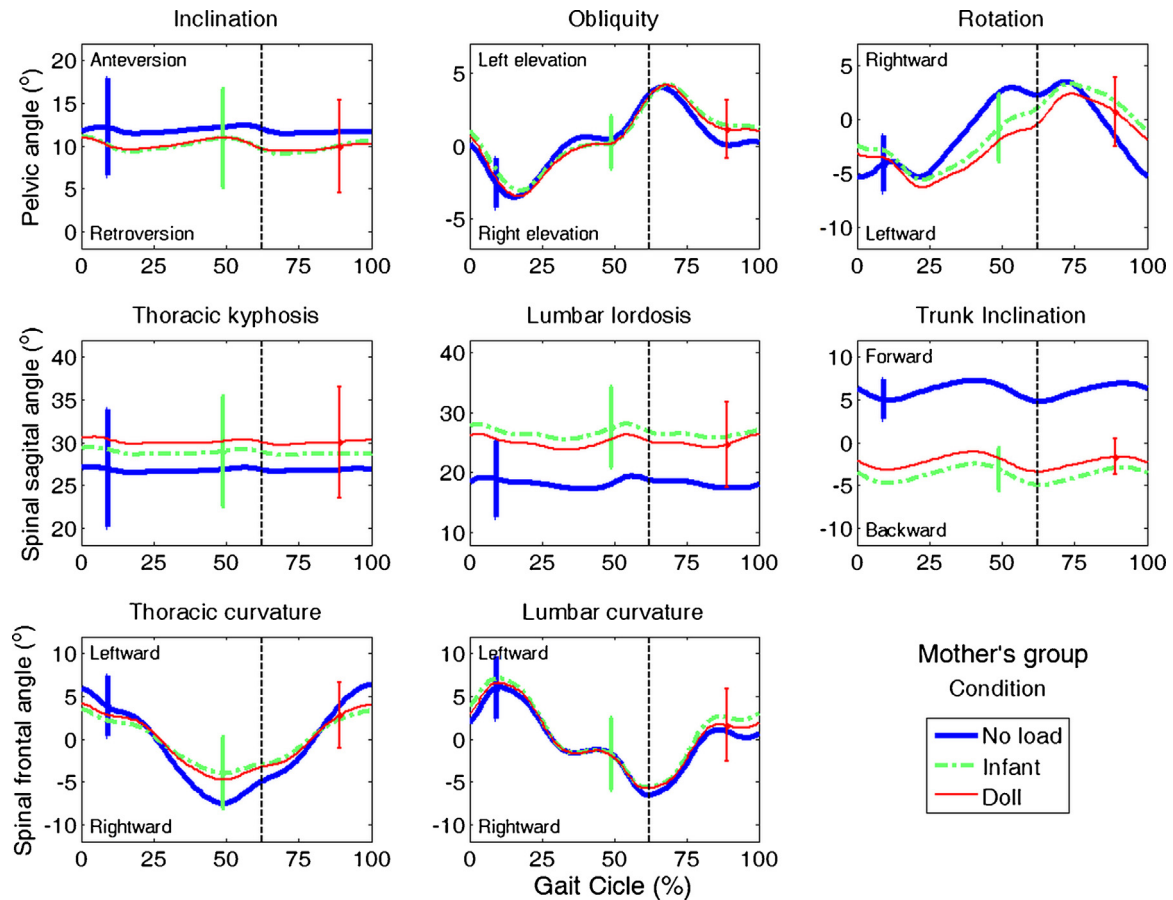


Fig. 3. Mean time series across subjects at each condition of the pelvic and spinal angles during one stride cycle (starting with the right foot) of walking for the group of mothers. For sake of clarity, the mean curve and only one ± 1 standard deviation vertical bar are shown for each condition. The dashed vertical line denotes the end of the support phase.

walking trials (the within-subject variability across all angles was on average $1.1 \pm 0.4^\circ$) with no effect of group or condition. However, the variability across subjects (between-subject) and across all angles was about four times larger, again with no effect of group or condition. But in the latter case, the pelvic inclination, thoracic kyphosis, and lumbar lordosis angles were about two times more variable than the angles of pelvic obliquity and rotation, trunk inclination, and thoracic and lumbar curvatures. This finding suggests that each woman presented individual pelvic and spinal postures at the sagittal plane, but the adaptations to carry a load were similar.

Carrying a load did not affect the average position of the vertical projection of the center of gravity (COGv) of the body plus load (either a doll or the infant) at the anterior–posterior and medio-lateral directions in relation to the unloaded condition

during standing still. This means that the women when carrying the load displaced their body COGv backwards to exactly compensate for the destabilizing load at the front, which resulted in no net change of the body-plus-load COGv during standing still. This compensatory strategy in the anterior–posterior direction has also been observed in pregnant women [14]. As the non-mothers were also able to perform similarly, this compensation does not seem to be specific to the pregnancy experience. Furthermore, we were able to determine that the compensatory strategy to balance the COGv were restricted to the upper body since no change was observed in the angle of the lower limbs with respect to the vertical. In addition, since the postural changes at the pelvis and spine during walking and standing still were similar, we interpret the postural changes during walking also as a compensatory strategy to balance the COGv in a dynamic task.

Table 2

Mean $\pm$ 1SD values of the angular variables across subjects at each condition of the mean value of the time series during walking.

Variable	Group				
	Non-mothers		Mothers		
	No load	Doll	No load	Doll	Infant
Pelvic inclination ($^\circ$)	14.2 ± 5.4^C	11.8 ± 5.4^C	$11.8 \pm 5.6^{C, NI}$	10.1 ± 5.4^C	10.0 ± 5.7^{NI}
Pelvic obliquity ($^\circ$)	0.0 ± 1.3	0.2 ± 1.5	0.3 ± 1.5	0.4 ± 1.8	0.6 ± 1.6
Pelvic rotation ($^\circ$)	-0.4 ± 2.5^C	-0.9 ± 2.6^C	-1.1 ± 2.0^C	-2.0 ± 2.8^C	-1.1 ± 2.7
Thoracic kyphosis ($^\circ$)	25.4 ± 3.9^C	28.1 ± 4.2^C	$26.8 \pm 6.8^{C, NI}$	$30.1 \pm 6.5^{C, NI}$	$28.8 \pm 6.4^{NI, DI}$
Lumbar lordosis ($^\circ$)	19.2 ± 6.4^C	24.9 ± 6.7^C	$18.3 \pm 6.2^{C, NI}$	$25.1 \pm 7.0^{C, NI}$	$26.6 \pm 6.6^{NI, DI}$
Trunk inclination ($^\circ$)	5.3 ± 2.0^C	-2.3 ± 2.8^C	$6.1 \pm 2.3^{C, NI}$	$-2.3 \pm 2.0^{C, NI}$	$-3.7 \pm 2.4^{NI, DI}$
Thoracic curvature ($^\circ$)	0.2 ± 2.3	0.3 ± 2.8	-0.7 ± 3.1	-0.3 ± 3.6	-0.3 ± 3.9
Lumbar curvature ($^\circ$)	0.7 ± 2.7	0.9 ± 3.1	-0.3 ± 3.0	0.2 ± 3.7	0.6 ± 3.7

The superscripts indicate significant main effects of group (G) and condition (C) and significant differences between infant and no-load (NI) or doll (DI) conditions for the mothers.

Table 3Mean $\pm$ 1SD values of the angular variables across subjects at each condition of the mean value of the time series during standing still.

Variable	Group				
	Non-mothers		Mothers		
	No load	Doll	No load	Doll	Infant
Pelvic inclination (°)	16.6 $\pm$ 5.1 ^C	11.7 $\pm$ 5.3 ^C	13.7 $\pm$ 5.5 ^{C, NI}	10.2 $\pm$ 6.1 ^C	9.6 $\pm$ 6.4 ^{NI}
Pelvic obliquity (°)	−0.1 $\pm$ 1.6	0.1 $\pm$ 1.6	0.6 $\pm$ 2.00	0.6 $\pm$ 2.1	0.4 $\pm$ 2.7
Pelvic rotation (°)	0.8 $\pm$ 3.2 ^C	−0.1 $\pm$ 3.8 ^C	−0.1 $\pm$ 3.1 ^C	−0.4 $\pm$ 2.8 ^C	−0.9 $\pm$ 4.2
Thoracic kyphosis (°)	24.2 $\pm$ 4.6 ^C	28.2 $\pm$ 4.4 ^C	27.4 $\pm$ 6.5 ^{C, NI}	31.2 $\pm$ 6.9 ^C	28.2 $\pm$ 9.3 ^{NI}
Lumbar lordosis (°)	23.8 $\pm$ 6.7 ^C	25.9 $\pm$ 7.1 ^C	24.5 $\pm$ 6.6 ^C	27.9 $\pm$ 7.5 ^C	28.2 $\pm$ 9.3
Trunk inclination (°)	4.6 $\pm$ 2.3 ^C	−2.7 $\pm$ 3.2 ^C	4.1 $\pm$ 2.9 ^{C, NI}	−3.6 $\pm$ 2.3 ^{C, DI}	−5.6 $\pm$ 3.5 ^{NI, DI}
Thoracic curvature (°)	0.6 $\pm$ 2.3	0.7 $\pm$ 2.9	0.3 $\pm$ 3.3	0.5 $\pm$ 3.8	−1.1 $\pm$ 7.2
Lumbar curvature (°)	0.4 $\pm$ 3.3	0.4 $\pm$ 4.2	−1.4 $\pm$ 3.0	−0.7 $\pm$ 4.4	1.9 $\pm$ 8.8

The superscripts indicate significant main effects of group (G) and condition (C) and significant differences between infant and no-load (NI) or doll (DI) conditions for the mothers.

The changes we observed during the standing still were similar to the changes observed during the walking task. In addition, in agreement with Frigo [15], who only investigated women walking while not carrying anything, we observed trunk flexion (forward inclination), decreased lumbar lordosis, and no consistent change in thoracic kyphosis during walking in relation to standing (for both unloaded and loaded conditions). These facts suggest that similar adaptations to carry a load occur in the two tasks.

Regarding the infant experience, we did observe some small differences in the spinal angles at the sagittal plane of the mothers carrying their infants compared to when carrying a doll. These differences were up to two degrees; the main change was an average increase of the trunk's backward inclination. It is possible that the mothers employed a protective strategy when carrying their infants. However, based on these results we cannot affirm conclusively that carrying an infant is different than carrying a doll regarding the posture of the mother during walking or standing. The fact that there was no difference in the walking speed and stride length between carrying an infant or a doll for the mothers might allow the interpretation that the specificity of being an actual infant and the bonding mother–infant are not influential factors on how the mother walks. However, the mothers always walked slower and with shorter strides than the non-mothers, and these two groups were not different in height, body mass, and age. This might be because the mothers unconsciously adopted the same speed to walk carrying a doll as they are used to do when carrying their infants. Thus, it is still possible that mothers are different than non-mothers because of the actual infant experience. However, at present, we are unable to address this speculation in more detail.

We investigated only carrying the infant symmetrically in front of the trunk, but mothers do carry their infants in different ways, such as at the sides, with a baby sling or other devices, or even with the help of another person. We also did not monitor how frequently and for how long the mothers have carried their infants. These factors might explain why the investigated mothers did not have any current musculoskeletal complaint, particularly back pain, despite its prevalence after pregnancy [8,10]. Nevertheless, the mothers did present two of the factors associated with back pain problems in this population: the excessive load to carry and the large mobility of the low back to adapt to such a load.

In conclusion, carrying an infant or a doll in front with the arms produces significant changes in the pelvic and spinal curvatures at the sagittal plane of women while walking and standing still. In addition, we observed some small differences in the spinal angles of the mothers carrying their infants compared to when carrying a doll. Overall, we consider these changes as a strategy to effectively compensate for the destabilizing load at the front and these changes are qualitatively similar to the ones observed during pregnancy.

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Conflict of interest statement

We declare that there is no conflict of interest of any of the authors related to this manuscript.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.gaitpost.2015.02.014>.

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