Static and dynamic biomechanical adaptations of the lower limbs and gait pattern changes during pregnancy

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The purpose of this literature review is to evaluate the studies that have investigated static and dynamic biomechanical changes of the lower limbs and gait patterns during pregnancy. Original articles on this subject, published between 1934 and 2012, were considered. In general, pregnant women demonstrated greater hip flexion, more extended knees and less plantar flexion ankles. These changes could explain the gait patterns of pregnant women characterized by increased hip angles, decreased propulsion forces associated with increased durations of stance phase and the plantar loads. This can lead to arthrokinematic deviations that, with time, contribute to the development of musculoskeletal discomfort. In summary, these findings showed the importance of further longitudinal studies to investigate the relationships between musculoskeletal discomfort in pregnant women in the lower limbs and gait changes observed throughout this period.

Pregnancy is a peculiar health condition, seen as a physiological process, that involves sequential modifications of the organs and corporal systems of women [1], which are of crucial importance for the establishment and progression of the pregnancy–puerperal cycle [2].

In particular, the musculoskeletal system suffers several soft tissue, joint and postural adaptations [3–5], which result in discomfort and pain of the vertebral column [6–9], hips [10,11], knees and feet [12]. Approximately 50% of all pregnancies incur pain in the pelvis and/or the lower back [13–15], which may persist or even increase, after delivery [16]. According to Moore *et al.*, the most interesting findings occurred between weeks 16 to 32 of pregnancy [17]. During this time, the changes in the lumbar curvature were significantly related to increased perceptions of low back pain, suggesting that the adjustments in the loading patterns of the lumbar spine, resulting from changes in its shape, plays an important role in the development of low back pain [17].

In addition, some changes in the body of the pregnant woman are caused by normal actions of certain hormones, such as progesterone, estrogen and relaxin [18]. Relaxin, the main inductor of ligament relaxation, leads to increased mobility of the pelvic complex [18,19] and the peripheral joints [20], which usually results in instabilities of the lower and upper segments that predispose individuals to lower limb dysfunctions [21]. However, the relationships between musculoskeletal changes and the role of relaxin hormone during pregnancy have not been fully explored [22,23].

Other specific aspects during pregnancy are the postural adaptations, which are necessary for the maintenance of equilibrium and better joint load distributions. The postural changes accompany continuous uterine growth and lead to increased loads on the anterior aspects of the trunk, mainly in the abdominal musculature [24] and changes in the center of gravity (CG) [25]. During pregnancy, the anterior displacements of the CG and subsequent posterior inclination of the thoracic segments associated changes of the pelvic posture occur [17,26]. Generally, the changes in the body during pregnancy include anterior pelvic tilt, increased lumbar lordosis [17,27,28], head posteriorization [29,30], knee hyperextensions and lowering of the medial longitudinal plantar arch, as well as increased volume [31,32], length and width of the feet [32].

These complex postural adaptations usually reduce the capacity of pregnant women in maintaining adequate posture without discomfort. Therefore, these changes generate compensatory adaptations, which could overload some body segments and lead to pain of the lumbar spine [13,33,34], hips [34] and lower limbs [12]. According to Ritchie, 20% weight gains during pregnancy may increase the forces over the main lower limb joints and this usually interferes with the quality of life of pregnant women [1]. Albino *et al.* reported decreases in the physical domain of the WHOQOL-BREF questionnaire [35], mainly during the third

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trimester of pregnancy. This physical domain represents the perceptions of pregnant women regarding complaints of pain and discomfort, energy and fatigue levels, sleep and rest, and mobility and work capacities. It is important to understand these complex postural adaptations so that we can more effectively treat a woman who is pregnant.

Subsequently, weight gains of approximately 12 kg [36,37] are associated with increased abdominal and breast volumes, mainly during the last trimester of pregnancy, contribute to increased overloads and imbalances of the musculoskeletal system [1]. These, in turn, lead to disturbances of the CG and greater oscillations of the center of pressure, which result in anterior–posterior imbalances [38,39]. To maintain stability in the standing position with all of these postural imbalances, women need to adopt strategies, such as foot repositioning, to increase their support base [40], leading to changes in plantar pressures [41].

The search for the maintenance of balance in the standing position can also be shown during locomotor skills, mainly during gait. Based upon this assumption, the literature described changes in angular kinematic [42–44] and spatiotemporal parameters [45] of pregnant women's gait. A locomotor pattern with greater mediolateral sway is observed, demonstrating shorter steps, a wider base of support and the feet more laterally rotated [40,46]. A better understanding of these gait modifications would result in more appropriate preventive approaches regarding painful complaints of these women, according to Wu *et al.* [14].

In this broad context of body and postural changes throughout pregnancy, this review attempts to evaluate studies that have investigated the static and dynamic biomechanical changes of the lower limbs and gait during pregnancy due to the importance of these anatomical and physiological changes of the body for the development of the fetus and the adaptations of the lower kinetic chain to cope with greater loads and motor challenges in their daily living. This review was justified due to the need to develop preventive strategies to relieve musculoskeletal discomfort and pain in the lower limbs, mainly during gait. Although gait is a repetitive cyclic task performed by pregnant women, typical patterns of static and dynamic biomechanical changes in the lower limbs during gait over the various stages of pregnancy, have not been previously reported. For this, a search was performed on the Scielo, Scopus and Medline databases between the years 1934 to 2012 to assess the changes in the lower limbs and their potential influences on gait biomechanics throughout pregnancy, to:

- Identify the postural adjustments associated with changes in the lower limbs and foot support positioning, and understand the musculoskeletal symptoms during this period;
- Verify and characterize the changes in gait patterns during pregnancy;
- Compare the levels of agreement and contradictions between the studies.

Static & dynamic biomechanical changes of the lower limbs during pregnancy

During the course of pregnancy, the increases in weight and anterior displacements of the CG are compensated by biomechanical changes that result in posterior displacements of the trunk centre of mass [1]. These biomechanical changes related to the realignment of the spinal curvatures include increases in lumbar lordosis, posterior upper body tilt and increases in the sagittal pelvic tilt. All of these postural changes aimed to absorb extra forces and ensure better postural balance [30].

Of all the spinal curvatures, the lumbar region is the most affected [17,27,28,30]. According to Moore *et al.*, the lumbar lordosis curvature significantly increases over the course of pregnancy [17]. However, Bullock-Saxton reported that besides the increases in the lumbar curvature, there is also an increase in the thoracic curvature, which is maintained up to 2 months after childbirth [47].

All of these postural realignments of the spinal curvatures can produce overloads in the main lower limb joints and lead to musculoskeletal discomfort and pain symptoms [1], which can be frequently associated with decreases in quality of life, mainly over the last trimester of pregnancy [48]. Some of these musculoskeletal discomforts are related to pain in the lumbar spine [6–9], sacroiliac and hip joints [10,11,49], and in the knees and feet [12]. It is estimated that approximately 25% of pregnant women demonstrate at least some temporary symptoms [5]. According to Hagan and Wong [50], pregnancy-related spinal and lower extremity changes should be monitored to prevent or reduce potential dysfunctions [3,48] and the loss of independence to perform daily living activities, such as bending down to pick up some objects, standing up from a chair, and even walking [13,51,52].

Generally, these functional limitations can be due to compensatory biomechanical adaptations caused by an increased body mass [36,37], the anterior displacements of the body center of mass [25,38,39] and hormonal changes that lead to increased joint mobility of the pelvic complex [18,19] and the peripheral joints [20], which can result in postural realignments [17,30,33,34] and more stress on the muscles [53]. The combined effects of trunk muscular dysfunctions and hormone-induced increased ligament and joint capsule laxities in pregnancy may increase the risk of insufficient muscular strength of the pelvis, resulting in pain. Thus, spasms of the back muscles were linearly related to pain scores [53,54]. It has been shown that the activation patterns of the back extensor muscles appeared to predict future back pain.

One observed postural change is the realignment of the upper trunk, in which the mobility range of the trunk in the standing and sitting position was examined in nine healthy, pregnant women with no pain symptoms and in a control group of 12 women, by way of video recording [28]. The results showed that in advanced pregnancy the forward flexion motions of the trunk were restricted, although not all trunk segments and postures were equally affected. The effects of pregnancy on forward trunk flexion were greater and observed earlier in the seated versus the standing postures. It may be expected that greater and earlier restrictions in seated movements would occur in comparison to standing, since the pregnant abdomen is in very close proximity to the thighs in the seated position and compensations by the hip joints are restricted by the chair seat and backrest. The standing forward flexion may have been difficult to perform in late pregnancy, as forward stability may be decreased [28]. Bending forward and trunk rotation were also on the list of problematic activities, which require the greatest effort in terms of reported energy expenditure in pregnant women. These activities also included reaching above head level, pushing, repetitive activities and working at high speeds [55]. In the task of changing the positions from sitting to standing, the pregnant women showed increases in knee loads and decreases in the net hip joint moments [56].

These functional impairments are mostly explained by the extensive stretching of the abdominal musculature, which were confirmed by Gilleard *et al.*, who examined abdominal stretching through 3D photographs during the nine different gestational periods (14–32 weeks) and 8 weeks after childbirth [57]. The authors observed that the lengthening of the abdominal muscles during pregnancy reduced the functional stability of the hip joints. This reduced stability remained for up to 8 weeks after childbirth.

According to Foti *et al.*, all of these postural and functional changes of the hips resulted in changes in the kinetic patterns of the whole lower limb [44]. As a result of these biomechanical changes, continuous overloads take place in the hip joints, which, over the course of pregnancy, can result in joint pain and stiffness. In some cases, in the presence of elevated adrenocortical activity during pregnancy, increased stressfrom weight gain in conjunction with increased interosseous pressure have been linked with necrosis of the femoral head [58–60] or even clinical signs of osteoporosis due to calcitropic hormonal changes [61,62]. However, the physiopathological mechanisms underlying these conditions are still neither well explained, nor understood.

Another aspect associated with pregnancy, and that could affect the static and dynamic biomechanics of the lower limbs, is the ligament laxity promoted by the hormone relaxin [19–21]. Relaxin is associated with the remodelling of the collagen fibers from large to small diameters, which activates fibroblasts for the syntheses of new collagen fibers [21,63]. The net effect of relaxin refers to ligamentous laxity that can lead to pain and dysfunctions of the lower extremities. During pregnancy, a tenfold surge of relaxin weakens soft tissue structures and increases joint flexibility [20,64]. As the foot is no exception to these hormonal influences, Block *et al.* revealed an increase in subtalar and first metatarsophalangeal joint ranges of motion in pregnant women [46]. However Alvarez *et al.*, attributed these foot changes to retention of fluid or to an increase in soft tissue, and not to stretching or relaxation of the ligaments [31]. The relationships between musculoskeletal and hormonal changes during pregnancy has not been fully demonstrated [22,23] and more studies need to be accomplished.

Based upon these findings, Vullo *et al.* reported that, after childbirth, 31% of the women had complaints of generalized pain in the feet and 42% of them reported pain in specific areas of the feet, such as the rearfoot, midfoot and forefoot [12]. Confirming the onset of these painful symptoms due to the relaxin hormone, studies demonstrated that during pregnancy tenfold increases in relaxin levels may occur, which weaken the soft tissue structures and increase joint flexibility [19–21].

Increases in the flexibility of the distal kinetic chain result in a more unstable pelvis associated with anteversion alignments and reduced dissociations between pelvis and trunk movements [52]. In addition, valgus misalignment of the knees takes place, due to the middle–lateral displacements of the center of the body mass of pregnant women [35,45]. Another consequence of the knee valgus misalignment is the increased moment of force over this joint, which can cause pain, joint instability and even the development of the patellofemoral syndrome [12,33,56]. These knee and hip misalignments can contribute to increased risks of developing various musculoskeletal dysfunctions in the body of pregnant women [65]. One common musculoskeletal complaint during pregnancy is the occurrence of leg cramps, which are characterized by involuntary sudden contractions of the gastrocnemius muscle [66]. The increased sagittal plane maximum ankle power absorption and the maximum ankle plantar flexion moment during gait, are both consistent with increased use of the ankle plantar flexor muscles due to increased body weight during pregnancy [44]. Ponnapula and Bogerg reported that these changes produce biomechanical disadvantages, such as stresses on the joints and muscles of the lower limbs during dynamic activities, such as gait [65].

Continuous stresses of the musculoskeletal system, which could lead to arthrokinematic changes, are related to the foot segments, which can be explained by the increased stretching of the plantar ligaments [31] and reduced proprioception [67], which make pregnant women more susceptible to sprains and pain symptoms in the plantar areas of the foot, since these segments are the static and dynamic bases of body support [67].

Changes of the foot structures during pregnancy are well documented in the literature. Wetz *et al.* [32] and Alvarez *et al.* [31] reported no changes of the length, but increased volume of the feet during pregnancy. Increased foot volumes of 57.2 ml between the beginning and end of pregnancy were attributed to the increased retention of liquids during this period. However, 8 weeks after childbirth, reductions of only 8.42 ml were observed [31]. These changes in volume appear to be related to increases in fluid or soft tissue in the foot, or both. According to the authors, if the increases in volume were solely due to the retention of fluids, it would be expected that they would be resolved after delivery because of the rapid diuresis that occurs after this period. Since they were not resolves, it was assumed that some of these increases in volume were also due to the accumulation of fluid in the soft tissues [31].

According to Block *et al.*, both the rearfoot and midfoot of pregnant women assumed a more pronated position, which was associated with the lowering of approximately 1 cm of the talus, and promoted reductions of the static height of the arch and increases of the movements of the subtalar and first metatarsophalangeal joints [46].

The effects of pregnancy on the plantar arch are still not clear [68]. Of the few studies, Jelen *et al.* employed 3D photogrammetric analysis to evaluate four women during the three trimesters of pregnancy [68]. They found no clear evidence of increased or reduced plantar arch height. Another single case report observed decreases in the height of the arch and increases of the width of the feet during pregnancy and that these changes still remained immediately after childbirth [69].

Due to anatomical changes of the feet, associated with ligament and soft tissue laxity, increased body mass, and greater demands on the abductor muscles, greater stretching of the plantar fascia could occur. Since the plantar fascia helps supporting the medial longitudinal arch, all of these changes could contribute to its lowering.

Adaptations of foot support to maintain postural balance during pregnancy

The maintenance of postural stability in the standing position is a complex task and, in spite of being common in daily life and during pregnancy, the woman's body seems to have already changed the postural control that during the last trimester, there is a trend to reduce the postural stability [39]. Some possible explanations are spine and lower limbs adaptations. The joint and muscular overloads, due to the increased body mass, are approximately 12–16 kg [36,37] and the superior and anterior displacements of the CG [25] could affect balance and the control of movements during pregnancy [48].

Oliveira *et al.* observed reductions of the static postural control during pregnancy in situations of reduced bases of support [70]. In agreement with the findings of Jang *et al.* [71], Ribas and Guirro [39] found significant decreases in postural balance during the last trimester, associated with increased anterior–posterior displacement of the movements during this period. According to Butler *et al.*, postural stability gradually decreases during pregnancy and remains reduced up to 6–8 weeks after childbirth [38].

All of the decreases in postural stability of pregnant women increase the risk of falls during this period, when compared with nonpregnant women. In the study of Dunning *et al.* [72], 3997 pregnant women were asked about health issues and activities at the time of the falls. Of these, 1070 (27%) reported falling at least once during their pregnancy, 35% fell twice or more, 20% sought medical care and 21% had two or more days of restricted activity. The women who fell were subjected to several types of injuries, such as bone fractures, muscular and articular stretching, soft tissue ruptures, displacements of the placenta and, occasionally, death of either the mother or fetus, or both [73–75].

In an attempt to maintain postural balance and decrease the risk of falls, adaptations of the foot segments were observed with increased bases of support of the feet [38]. Studies during pregnancy showed the influences of the base of support configuration (wide/narrow) and the visual input (eyes open/closed) on the center of pressure (COP) displacement areas [38]. Oliveira *et al.* conducted stabilometric tests with 20 pregnant women during the three trimesters by combining different visual conditions (eyes open/closed and support bases (feet together/apart) [38]. They found lower COP displacement areas with the eyes open and the feet apart and higher values with the eyes closed and feet together, as in the present study. Dumas *et al.* (1995) [33] and Butler *et al.* [38], emphasized that the wider base of support of the feet during the third trimester of pregnancy, was required to better control the postural stability. Bird *et al.* [40] employed simple resources, such as plantar impression parameters, to evaluate 25 women at 12 weeks of pregnancy. While longitudinally and transversally measuring the registered plantar impressions, they observed increases of the bases of support from the first to the last trimester. This finding was explained as a compensatory mechanism of pregnant women to improve their locomotor stability. However, this strategy could have important implications for the functional mechanisms of the feet related to load absorptions and distributions [76]. Nyska *et al.* [41], Goldberg *et al.* [77] and Ribeiro *et al.* [76] reported that a greater base of support provided an increased contact area of the foot with the ground. According to Block *et al.* [46], increases in the area of contact of the lateral rearfoot and medial midfoot could be explained by greater medial–lateral oscillations of the CG, as reported by Lymbery and Gilleard [45].

For Lymbery and Gilleard [45] and Mocelim *et al.* [48], pregnant women tried to maximize their postural stability and control of the sideways movements, by adjusting their step width. This strategy requires the adoption of walking patterns that produce changes in the joint segments and lower limb muscles, which result in excessive plantar overloads.

Gait adaptations during pregnancy

The clinical assessment of gait of pregnant women can be important for a better preventive treatment of musculoskeletal discomfort during pregnancy [44]. One of the explanations for this are all postural modifications that will potentially lead to compensatory mechanisms which may overload some bodily segments and provoke pain and discomfort [13,14,17]. In addition, weight gains and the resultant uterine growth increases the load on the anterior part of the trunk and lead to changes in the CG [34]. These changes result in greater oscillations of the COP in the anterior–posterior directions [78], which lead to medial–lateral oscillations of the CG in pregnant women [45]. In static and dynamic postures, the pregnant women use a repositioning strategy the foot on ground to increase their bases of support and maintain stability [40,41,46,76,77]. This effort to maintain equilibrium can also provoke changes in walking patterns of pregnant women [45]. Until the present, descriptions of gait biomechanics of pregnant women found in the literature referred to kinetic variables, such as ground reaction forces [35,44,45] kinematic [44,50,79], spatiotemporal parameters [42,43,45,79] and plantar loads [41,76–78].

One of the first studies of gait during pregnancy, performed by Taves *et al.* [42], evaluated the spatiotemporal parameters in the sagittal plane (step width and length) at the end of the last trimester of two women. No significant differences were found regarding these variables, when compared with nonpregnant women. However, the authors admitted that modifications in the frontal and transverse planes were not considered, thus, the findings should be taken with caution. In this direction, Golomer *et al.* investigated 10 women between the third and eighth month of pregnancy and also observed that step length and gait speed did not demonstrate significant changes over the evaluated period [43]. According to these studies, pregnant women showed no changes in gait during the gestational period. Thus, for the better understanding of gait adaptations during pregnancy and clarification of the results of the studies which did not observe gait pattern changes of pregnant women, Foti *et al.* carried out 3D analyses with 15 women during the second and last trimesters of pregnancy and 1 year after delivery [44]. They found increases in maximum anterior pelvic tilts, maximum hip flexions and in the moments of force of the hip abductors and extensors and ankle plantar flexors during the terminal stance phase. The maximum anterior pelvic tilt remained increased 1 year after delivery. These compensations occurred due to weight increases and changes in the distributions of the body mass during pregnancy. They suggested that these compensations could promote muscular overloads on the lower limbs and lead to pain in the hip, knee and ankle joints.

Confirming these gait changes, during pregnancy was found in the literature more recent studies. Hagan and Wong, employing 2D analysis in the sagittal plane, evaluated the gait of two women before and during pregnancy (first, second, and third trimesters), and also 16 weeks after delivery [50]. Contradictorily, they found that after childbirth, the changes in the hip angles, and pelvic inclinations returned to values observed before pregnancy. However, the reduced ankle plantar flexion angles observed during pregnancy remained 16 weeks after delivery. This reduced ankle plantar flexion angle also was observed by Albino *et al* [35]. The authors observed reduced propulsion forces and higher mediolateral oscillations during pregnancy. Based upon these findings, they suggested that the decreased propulsion forces could result in overloading of the plantar flexor muscles, as suggested by Foti *et al.* [44].

Regarding the angular changes of the hips and ankles during gait of pregnant women, some studies have reported changes of the foot support with the ground to maintain stability of the body. These changes of the feet were shown by Lymbery and Gilleard [45], when comparing the spatiotemporal parameters and ground reaction forces during gait of 13 pregnant women at approximately 38 weeks of pregnancy and 8 weeks after delivery. They observed that the women demonstrated wider steps during pregnancy, compared with 8 weeks after delivery. In addition, they found that the lateral component of the ground reaction force was higher and the COP during the initial phase of the static support was shifted more medially and anteriorly. They suggested that the gait patterns with mediolateral oscillations adopted by pregnant women were required to maintain postural stability during the stance phase of gait. Corroborating these findings, Carpes *et al.* also found increased step length and width from the second to the last trimester of pregnancy associated with increases of the stance phase times from the first to the last trimester of pregnancy [79]. These changes were maintained for up to 4 months after childbirth.

Besides the support of the feet on the ground during gait studies have also demonstrated plantar load changes on feet during pregnancy. Nyska *et al.* evaluated the static and dynamic plantar pressures of 28 nonpregnant and 25 pregnant women during their last gestational week [41]. They found that in the static position, pregnant women had significantly lower maximal forefoot and higher rearfoot pressures than the nonpregnant ones also associated with increased areas of contact. Regarding the dynamic pressure, higher contact times and peak pressures on the lateral areas of the plantar surfaces were observed. The maximum force on the heel was increased approximately 15% for the right leg and 10% for the left leg. They explained these findings with the combination of the anterior displacements of the center of mass, forefoot pronation, heel volume and accumulations of soft tissues, fat or edema of the feet. They speculated that changes in plantar pressures could be associated with pain in the feet of pregnant women. Goldberg *et al.* also found that, in the last trimester, the peak pressures remained increased in the rearfoot and reduced in the forefoot, the increased contact times indicated reduced gait speed and increased impulses, or the integral of the forces [77]. In contradiction, Karadag-Saygi *et al.*, observed increases of the peak pressures in the forefoot during both the static positions and in gait associated with greater oscillations of the COP in the anterior–posterior directions and increased contact times in the forefoot, promoting an extension of the support phase in the midfoot area, which were correlated with the symptoms of pain in the feet [78].

To better clarify the contradicting results on increased peak pressures in the rearfoot or forefoot, one longitudinal study was found on gait of pregnant women. Ribeiro *et al.*, in a 1-year follow-up study, evaluated the static and dynamic plantar pressure distributions of six pregnant women and observed no differences of the plantar pressures during static postural balance [76]. However, during gait, the peak pressures and the maximal forces on the medial rearfoot were reduced between the first and last trimesters of pregnancy. Increases in maximal forces were seen on the medial forefoot between the first and second trimesters, in the contact areas of the lateral rearfoot over the last trimester, and in the contact times of the midfoot and forefoot from the first to the last trimesters. Thus, during pregnancy, there was an observerd redistribution of the plantar loads, which decreased plantar loads on the rearfoot and increased in the midfoot and forefoot. These findings do not corroborate those reported by Nyska *et al.* [41] and Golberg *et al.* [77], but are in agreement with the results of Karadag-Saygi *et al.* [78].

In the present literature review, it can be seen that increases in hip angles associated with greater moments of force of the hip extensors and abductors [44] and decreases of ankle plantar flexion angles associated with decreased push-off forces [35] resulted in increased step length and width [79] that led to higher plantar loads on the forefoot and rearfoot regions [41,76,77] and greater sway anterior–posterior and mediolateral body sways of pregnant woman [45]. These changes may be due to weight gain and the anterior offset of the CG, more anteriorly over the course of pregnancy along the growing fetus. Thus, many of the musculoskeletal problems associated with pregnancy may be due, in part, to consequences of secondary gait deviations to compensate for increased body mass and anterior displacements of the CG. Physicians caring for pregnant women with musculoskeletal dysfunctions should emphasize the importance of exercises during pregnancy for the prevention and management ative and rehabilitative treatment of pain, and stresses in the joints and muscles of the lower limbs that can occur during this period [80]. Research has shown the benefits of exercises during pregnancy for both the mother and fetus. The type, intensity, frequency and duration of the exercises seem to be important determinants of their beneficial effects. Maternal benefits include improved cardiovascular function, decreased weight gains, reduced fat retention, lower stresses on joints and muscles stress, improved attitudes and mental states, easier and less complicated labor, quick recovery and improved fitness [80].

Two types of physical therapy interventions could be addressed in future studies. First, one possible therapeutic resource would be the prescriptions of orthoses for the support of the

Executive summary

Background

- During pregnancy, postural adaptations are necessary for the maintenance of equilibrium and better joint load distributions during gait.

Static & dynamic biomechanical changes of the lower limbs during pregnancy

- Most of the changes during pregnancy are caused by static postural adaptations, such as increased lumbar curvatures and pelvic inclinations, reduction of the dissociations between the movements of the pelvis and trunk, knee valgus misalignments, and possible reduction in the longitudinal arch height.
- All of these lower limb postural changes result in decreased postural stability, ankle plantar flexion and foot proprioception.

Static & dynamic biomechanical changes of the lower limbs during pregnancy

- The maintenance of postural stability in the standing position is a complex task, and in spite of being a common daily life activity during pregnancy, the woman's body seems to reduce postural stability. Some possible explanations are spine and lower limb adaptations.
- The postural stability gradually decreases during pregnancy and remains reduced up to 6–8 weeks after childbirth. All the decreases in postural stability of pregnant women increase the risk of falls during this period.
- In attempting to maintain postural balance and decrease the risk of falls, adaptations of the foot segments are observed with increased bases of support and the distances between the feet.

Gait adaptations during pregnancy

- The gait patterns of pregnant women are characterized by greater hip flexion angles, greater extensor and abductor hip moments, and longer stance phase durations from the first to the last trimester of pregnancy. These changes were maintained up to 4 months after delivery.
- In addition, decreases of the plantar flexion and the propulsion forces resulted in longer step lengths and widths and greater anterior–posterior and medial-lateral sways All of these gait changes resulted in redistributions of the plantar loads with increased loads in the forefoot and decreased loads in the rearfoot throughout pregnancy.

Clinical findings & future perspective

- All of these findings suggest that physiotherapists, within their clinical practice, should observe and propose intervention programs that emphasize postural balance and the prevention of falls by the maintenance of adequate tonus and strength of the lower limb muscles, particularly in the hips, to be able to cope with the higher force demands during functional and static activities.

medial–longitudinal arch to provide comfort and better redistribution of the plantar loads. Another intervention could involve the design of appropriate shoes, which would allow better postural sways, safety and performance of the lower limbs during gait with fewer stresses in the joints and muscles.

Conclusion & future perspective

In general, women change the static alignment and range of motion of the hips, knees and ankles in a static posture during pregnancy. These changes could explain the gait patterns of pregnant women, characterized by lower propulsion forces, longer stance times and higher plantar loads over the rearfoot and forefoot. Thus, many of the musculoskeletal pain and discomfort in pregnant women may be a consequence not only of the compensatory adjustments due to the body mass increases and anterior displacements of the CG, but also may be related to biomechanical gait changes usually observed in this population. All of these findings show the importance of further longitudinal studies to investigate the relationships between musculoskeletal discomfort in pregnant women and lower limb adaptations and gait changes observed throughout this period. Another important investigation is to study the effects of physical therapy interventions during pregnancy to prevent biomechanical compensatory strategies, which promote joint and muscle stresses on the lower limb during gait.

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