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Review Article

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A Review: Biomechanical Substitutions during Pregnancy and Application of Orthoses

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ABSTRACT

Pregnancy-related biomechanical adjustments might result in alterations in gait patterns. These modifications can change spine balance, curvature, and ambulatory patterns during pregnancy by influencing important parts of the body. The musculoskeletal system's responses to structural substitutions during pregnancy are not entirely apprehended. As a result, the primary goal of this review is to gather the important biomechanical replacements that affect gait patterns during pregnancy. Furthermore, these biomechanical alterations are investigated in-depth, and several orthotic interventions are proposed to combat these changes; nevertheless, it has yet to be determined whether or not orthoses are advantageous during pregnancy. In the light of literature, some pieces of evidence are included, but suitable guidelines are lacking to gain a better grasp of pregnancy biomechanical changes and the effect of orthoses.

KEYWORDS: Pregnancy, Gait Analysis, Orthotics, Orthopedic, Biomechanics, Balance.

INTRODUCTION

Pregnancy alters the physiology, anatomy, morphology, body composition, musculoskeletal and endocrine systems of mothers [1]. Women go through a variety of changes of 38–42 weeks, the most visible of which are musculoskeletal adaptation, increased weight, and skeletal misalignment. The rise in maternal size, weight, and weight of the foetus, the increase in breast weight, and the maternal abdomen all contribute to the development of the spinal inward curve, which causes a change in the centre of gravity of the feminine body [2]. Such impacts are very certainly the result of many biomechanical and hormonal swings that arise during labour. Increased peaks of relaxin are believed to be accountable for increased ligament flexibility and, as a result, alterations in the body's morphology, especially in the lower trunk. Changes in the curvature of the spine, such as kyphosis and lordosis, are also observable. Nonetheless, the impact of these morphological abnormalities in pregnant women is connected with changes in standing and sitting. This affects balance, as well as alterations in limb kinematics during gait as a result of ergonomic shifts caused by pregnancy [3].

When considering gait characteristics, numerous studies have found a reduction in gait velocity and an expansion in step width. Modifications in joint kinematics during locomotion have also been documented, with many pregnant women exhibiting decreased hip flexion and extension, among other consequences [4]. The changed ankle, knee, and hip motions and biomechanical alignments in all directions, with variations in the trunk kinematics of the connection between the torso and the pelvis change the center of gravity of the entire body. In terms of posture, research has found that pregnant women had considerably higher lordotic angles than non-pregnant women [5]. Differences in the center of mass (COM) are utilized as a marker of equilibrium in terms of balance. Evidence suggests that COM in expectant mothers has dramatically increased route length in many situations, indicating decreased stability.

To counter such biomechanical mal-alignments, this review tries to fill the gap between pregnancy management and orthoses usage. It also gains trust by proposing certain ways to reduce the risk, such as wearing proper footwear with inserts providing pain management, further pelvic belts are currently being used to treat pelvic girdle discomfort during pregnancy [6,7]. Compiling all relevant existing material should provide future researchers and orthotists with a better understanding of the biomechanical changes and risks in pregnancy that need additional transformation to increase

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QOL and lessen any discomfort or concerns to pregnant women. Further, this review investigates the following points which are the core objectives of this discourse:

- Using literature to identify biomechanical changes in pregnancy.
- Suggestions for orthotic interventions to reduce biomechanical changes that raise the likelihood of painful foot, knee, hip, and spine conditions.

Biomechanical Substitution in the Upper Limbs

The responses of the musculoskeletal system to structural changes throughout gestation are not well apprehending. Postural abnormalities can be produced for a variety of reasons, including gravid uterine enlargement, weight increase, superior and anterior shifts in the ligaments, centre of mass, soft tissue flexibility, and hormonal swings. Therefore, it is crucial to comprehend any possible impacts of gestation on the locomotor pattern. The following are some highlights from this review about variables influencing gait patterns during pregnancy:

Spinal Posture: To cater for the developing uterus with maintaining the respiratory function, the chest cavity expands laterally by 10–15 cm. The increase in the circumference of the chest is associated with increases in the subcostal angle, which is followed by pulling of the intercostal and abdominal muscles. These alterations have been linked to rib or costochondral discomfort during pregnancy. The spine curvatures, with the functional and structural capabilities of the ligamentous spinal and muscle stabilizers, change throughout pregnancy. Among the most noticeable changes is cervical kyphosis, intensified thoracic kyphosis due to increased mammary tissue, and enhanced lumbar lordosis [8].

These skeletal alterations are related to rhomboid and other upper back muscle overstretching in the setting of increasing ligamentous laxity and kyphosis, which decreases spine stability. In reaction to these postural alterations, the pectoral muscles shorten, increasing depression and shoulder rounding. In the lumbar area, however, the growing uterus and adaptive shortening of the paraspinal muscles and accompanying lordosis produce abdominal muscular stretching. Excessive loosening of the posterior and anterior longitudinal ligaments of the spine accords to decreased spinal stabilization and affects the muscular spinal stabilizers when the anterior abdominal core muscle tension is compromised. Once the uterus hit around 40% of the replete mass, there is a detectable rise in lumbar lordosis. Researchers have expressed particular interest in the mechanics behind the emergence of increased lumbar lordosis because of the high rate of low back pain during pregnancy [8].

One putative mechanism involves the roughly 6–7 kg gain in abdomen weight pushing the COM anteriorly, resulting in an eightfold increase in front torque at the hip joints. As human beings are biped, this front torque must be countered by paraspinal muscle activation to maintain posture. The uterine mass grows by stretching inferior and anterior ligaments and muscles, and the lumbar para-spinal muscles gradually activate to provide sagittal plane equilibrium, improving lumbar lordosis. Full-term lumbar spine extension is observed to be 18o-10°. The spinal correction for the uterus's growing bulk and size provokes increased lever arm and force (Figure-I), raising zygapophyseal facet joint shear stress by up to 60 percent [8,9].

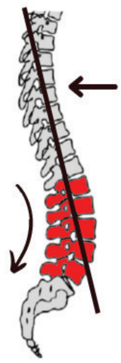

Figure-I: To restore sagittal stability, an adaptive rise in lumbar lordosis transfers the COM back to the neutral position over or slightly posterior to the hip joint center.

Orthotic Intervention: As an orthotic intervention for pregnancy-related spinal mal-alignment maternity orthoses is used including support binders, belly wraps, and other similar devices significantly reduced average pain scores and the influence of pain on ADLs. Users accept the application of a support binder for pregnancy-related low back pain as a practicable treatment [10].

Pregnant women can considerably reduce back and pelvic discomfort by using modified or customized belts with pelvic-girdle and lumbar support. Belts can also assist pregnant women to enhance their function and lessening their incapacities [11].

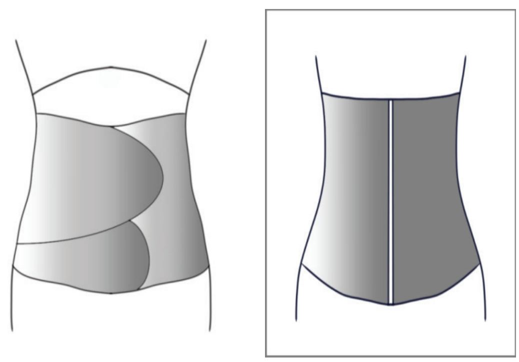

Figure II-III: Different types of Belly Wraps (Velcro) left and (Zipped) right.

Biomechanical Substitution Lower Limbs

During gestation, the lower limbs go through a lot of changes. While each lower limb component may be analyzed separately, it is vital to remember that the lower limb component act as a collective unit, with each component adjusting to the kinetic chain. Let's discuss each of them below:

Feet: Although the feet may have effectively supported and distributed body weight previous to pregnancy, changes during pregnancy might damage these supporting systems. During pregnancy, ligamentous laxity increases, resulting in a decrease in the height of the transverse and longitudinal foot arches [12]. Furthermore, shallower foot arches before gestation may have deteriorating flat feet. Fallen foot arches result in increased pronation which may affect loading patterns across the lower limbs. Foot pronation and lateral foot pressure are increased when the talar head is lowered by 1 cm [13]. Internal tibial rotation induces mal-positioning of the patella and anterior pelvic tilt when the foot pronates. Foot pronation of 2° or 3° has been shown to enhance anterior pelvic tilt during stride by 50–75% [14].

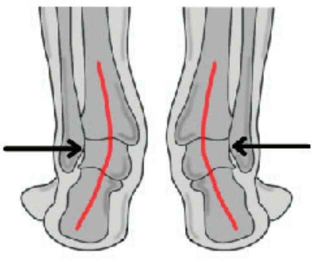

Figure-IV: Foot pronation as a result of a reduction of longitudinal and transverse arch height.

Orthotic Intervention:

For fallen arches during pregnancy and several biomechanical alterations foot orthoses and insoles might be beneficial. After reviewing the literature, it was observed that prefabricated and custom-made foot orthoses helps reduce posterior foot pain and promoting foot functioning. Some individuals indicated that anterior night splints helped them sleep better, especially if they had calf tightness [15].

Foot orthoses also appear to reduce ankle inversion angles while increasing mid-foot plantar pressures and force [15]. Furthermore, because arch height is associated with an increased risk of musculoskeletal diseases in the post-reproductive years, arch-supporting orthoses might be a cost-effective intervention if successful in avoiding deleterious foot alterations associated with pregnancy [16].

Knee: The impact of rear-foot pronation and pelvic tilt is almost immediately transferred to the knee via the distal to the pelvis and joint proximal to the foot. The knees must offer support and stability to the body while still allowing movement, including correcting modifications in the biomechanics of joints. The knees rely substantially on ligamentous support to do this. The knees are prone to deformity during pregnancy due to their reliance on ligamentous constraints. As uterine mass increases, the COM slips anteriorly, requiring the knees to adapt to maintain an upright posture. This is accomplished by hyperextension, which may develop to genu-recurvatum. To maintain an upright posture, the hips must also adjust. Knee discomfort during the second part of pregnancy might be exacerbated by postural changes, weight gain, and ligamentous laxity [17].

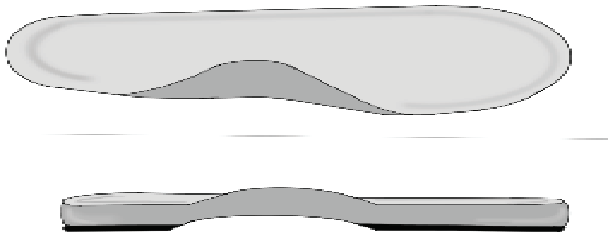

Figure-V: A top-view of the insole (a hump acts as a support to uplift the foot arches).

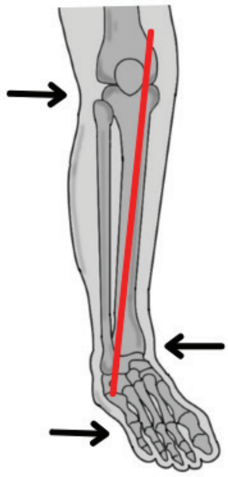

Figure-VI: Foot pronation causes the tibia to internally rotate, causing the knee ligamentous supports and the iliotibial band to stretch.

Hips: The hips must adjust during pregnancy due to the impact on iliotibial bands rear-foot and pronation on the knees, as well as alterations in the pelvis and centre of mass. To compensate for growing abdominal bulk and an anteriorly moved COM, the hips must transfer weight to maintain equilibrium. To accomplish this, the femoral heads rotate externally and the pelvis tilts anteriorly, both of which help to broaden the base of support. During pregnancy, hip extensor muscle and hip abductor activation increase, yet pelvic mobility varies depending on the job [18].

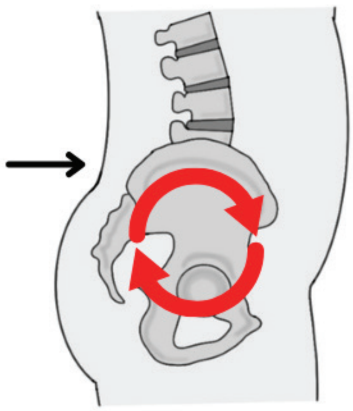

Figure-VII: Anterior pelvic tilt compensates both distal internal rotation and the requirement to minimize the hip flexion moment arm by shifting the COM closer to the hip axis.

Orthotic Intervention:
Belly or pelvic bands can be worn elevated at the anterior superior iliac spine and demoted at the pubis with a customizable broad and firm belt with metal stabilizers in the lumbar area that can be utilized to correct for anterior pelvic tilt. Various similar studies have revealed that pelvic belts considerably reduce sagittal rotation in the sacroiliac joint (SIJ) and that maintaining a belt beneath the anterior superior iliac spine (ASIS) greatly reduces SIJ laxity when compared to keeping it at the symphysis level [11].

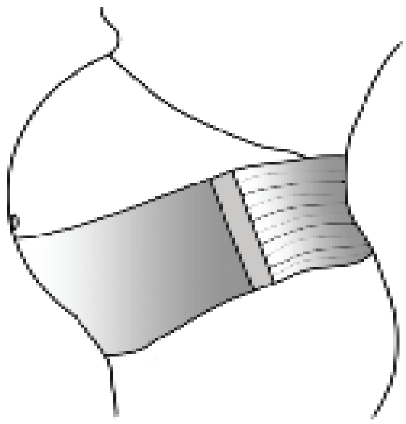

Figure-VIII: A belly band.

Biomechanics During Pregnancy

Changes in Joint Angulation: Merely a few scholars considered the angular alterations of the lower extremities. It was found that in the third trimester, there was an increase in maximum stance phase hip adduction and hip flexion. During stance, hip flexion increased in the experiment, whereas hip extension angle rose in another investigation [19]. A study revealed a reduction in adduction within the stance phase and right hip extension between pregnancy trimesters as compared to non-pregnant women [20]. They found no alterations in the transverse plane of the hip joints between the 2nd and 3rd trimesters or between pregnant and non-pregnant women.

In the knee joint, an increase in left knee flexion during pregnancy is observed [21]. In addition, substantial alterations in the knee joint between 40 to 50 percent as the gestation progressed [22]. On the contrary, there was a single case where ankle dorsiflexion was reduced (by at least 5°), but no variations in angular position of the feet were documented. Another study concluded, an increase in right ankle plantar-flexion during the second and third trimesters, but no significant variations were observed in the transverse plane, and no differences were observed between pregnant and non-pregnant situations [12].

Centre of Mass: The COM is a disposing of pressure exerted by the body to the ground via the soles of the feet. Analyzing deportment in the 1st trimester indicated negligible bigger COM regions than in all postures groups, presumably specifying increased instability in the trimester [23]. There were no variances in any of the COM parameters between the gestation women in the 2nd trimester and the control group. Examining the foot loading pattern during the 2nd trimester, on the other hand, revealed a 10% increase in maximum force in the medial forefoot from the first to second trimester [24,25].

Many researchers concluded considerable forward and medial displacements of the COM in late pregnancy. Although in the study, when the patients were expectant mothers who reported falling, the COM movement was reduced. Several studies have also found that higher mediolateral excursions of the COM during rising occur in the 3rd trimester. During advanced pregnancy, the anterior-posterior braking impulse was higher in both climb and drop. Throughout gestation, plantar loads were shifted from the rear foot (reduction) to the mid-foot and forefoot. The lateral rear-foot contact area increased significantly from the 2nd to the 3rd trimester, as did the mid-foot contact area from the first to the third trimester [26,27,28].

Moment of Force: Moments of force generated throughout various joint motions recorded by different studies decreased and increased. It has been found that maximum torque plantar flexion in the ankle is increasing [29]. Furthermore, no changes in knee moments of force were seen throughout pregnancy or the postpartum period. The involvement of the ankle plantar flexors decreases significantly from the first to the third trimester in the right ankle and increases from late pregnancy to the postpartum period in the left ankle. Because the longitudinal impact of pregnancy was not evident in the frontal plane, no significant changes in any of the studied variables were reported. In another trial, it was shown that the kinetics of the hip joint in the sagittal plane exhibited a substantial reduction in the participation of the hip extensors during the loading response phase, which is strongly related to pregnancy. The engagement of the knee joint flexor and extensor remained consistent during pregnancy in this investigation [29]. It was also found that normalized hip abduction moment during standing considerably increased during pregnancy, but normalized maximum ankle plantarflexion moment reduced significantly during pregnancy [30].

Ground Reaction Forces: The ground response forces were another characteristic that varied with the pregnancy stage (GRF). In late pregnancy, the vertical component was found to be decreased. According to a study, women's mechanical loads decreased throughout pregnancy, as evidenced by decreases in joint moments, GRF, and joint powers in the sagittal plane. Gait during gestation does not alter significantly kinetically from that of non-pregnant women. However, due to the increased bodily mass in pregnant women, the medial-lateral components were changed. It was also identified the medial aspect of the GRF as a motor response to improve stability for the majority of the stance period. In the third trimester, lower minimum and maximum levels of the anterior-posterior horizontal aspect of the GRF were recorded. In the second trimester, they detected the identical sequence of horizontal anteroposterior GRF elements as in the first [31].

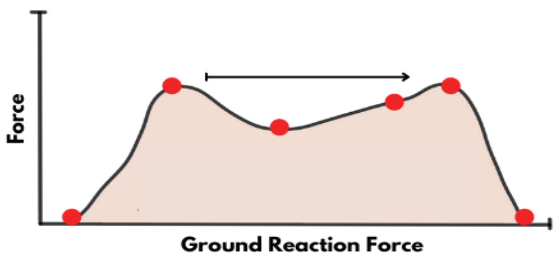

Figure-IX: A normal graph for ground reaction forces in the lower limb.

It was also observed considerable variations in the vertical component of GRF when going down the stairs while dealing with discrepancies in the compensation of gestation women on climbing up the stairs. During ascending walking, no such changes were seen. In both climb and descent, the anteroposterior braking impulse was larger in pregnant females.

Spatial and Temporal Parameters: A single gait cycle may be divided into two parts: the stance phase and the swing phase. The stance phase begins at the initial instant of foot contact with the floor and continues until the foot is no longer in touch with the floor. Toe-off marks the start of the swing phase. Any time when both limbs are in contact with the floor is considered double support, and any time when only one limb is in contact with the floor is considered single support [32,33]. Pregnancy is associated with a reduction in stride length [32,33]. Along with this, pregnant women have a wider step width, which is highest during the third trimester and thereafter decreases in the postpartum period. The literature extensively covers the hypothesis that pregnant women employ larger step width to strengthen their base of support and hence their stability during gait, which is equally applicable to static settings. One research also found that during pregnancy, the foot orients itself more towards the outside. Despite these substantial findings, previous studies have found that pregnancy does not influence stride length or stride breadth. Pregnancy reduces gait velocity in the short term. However, studies discovered that gestation had no influence on gait velocity at lesser speeds and only lowered velocity at faster rates [32,33]. Single limb support time was shown to decrease during pregnancy while double support time increased. Pregnant women had shorter swing phases and longer stance phases than non-pregnant women. Pregnant women have a substantial link between a drop in stride length and a decrease in gait velocity [32,33]. Along with measuring gait modifications at high and low speeds, women were instructed to ambulate at their own pace. Lower velocities are seen among pregnant women in these tests, which is thought to be due to a fear of falling.

DISCUSSION

Anatomical and biomechanical changes, as well as hormone imbalances, enhance joint forces and joint flexibility. These conditions may lead to joint discomfort, impaired coordination, and an enhanced risk of injury. Furthermore, the repercussions may range from mild to intense pain which disappears postnatal to major clinical musculoskeletal ailments that lead to additional health problems. These circumstances may make it difficult for women to be healthy and active or exercise throughout their pregnancy and afterward. To counter such biomechanical mal-alignments, this review tries to fill the gap between pregnancy management and orthoses usage. It also gains trust by proposing certain ways to reduce the risk, such as wearing proper footwear with inserts providing pain management, further pelvic belts are currently being used to treat pelvic girdle discomfort during pregnancy [6,7].

According to one study, using a maternity orthosis can considerably decrease pain ratings and the consequences of pregnancy-related lower-back discomfort. The low cost of the support, convenience of fitting, and rarity of adverse effects indicate that this technique has potential for usage throughout pregnancy. Individual's weight, size, or obesity will not affect the fit of the binder because these orthoses may be tailored to their specific needs [10].

Another study reported that pregnancy is linked to arch height drop, with the first pregnancy being the most important. These alterations in the foot may contribute to women's higher risk of musculoskeletal problems. They concluded that a combination of ligamentous laxity and changes in biomechanics occurs with abnormalities in foot anatomy, which can impair the usual regulation of forces transmitting from the foot to more proximal lower limb joints and the spine, and may lead to discomfort in the feet, knees, and hips. Based on the evidence gathered, it was proposed that using arch support decreases foot discomfort during pregnancy [34]. Nowadays a new term in gyration known as dynamic elastomeric fabric orthoses (DEFO) - such types of orthoses are being used in many areas including, sports, athletics and also being applicable for pregnancy-related deformities. It is suggested that wearing a DEFO during pregnancy might have a beneficial effect on pain management and functional ability. However, there is minimal data to show that using a DEFO through pregnancy may have an impact on quality of life. More study is needed to assess the therapeutic value of using a DEFO for postnatal women. Future research on this subject should include standardized outcome measures, uniform DEFO criteria, precise product specifications, and strong study designs to draw reliable conclusions and, when relevant, incorporate research data in clinical practice [35].

CONCLUSION

It is concluded that pregnancy has evident effects on a woman's biomechanics including lower and upper limb. These changes make it difficult to achieve the ADLs connected to QOL. According to the literature review, it is observed that the usage of orthoses in pregnancy can have a significant and positive role in uplifting the discomforts and pains. It is also suggested that orthoses can be prescribed during pregnancy, which can be cost-effective and adequate means of intervention as it is identified that a handful of discomforts are originated from biomechanical aspects and can be rectified by orthoses.

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CONFLICT OF INTEREST: It is to declare that, all the figures added in the manuscript are re-designed by me and there is no conflict of interest.

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Author's Contribution:

Usama Bin Yar: Designed study, collected data, formation and made illustrations.

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