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LITERATURE REVIEW

Postural Changes And Movement Biomechanics In Pregnant Women: A Literature Review

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Background

Pregnancy is a remarkable physiological process that is essential for human reproduction and the continuation of life. During this period, the maternal body undergoes extensive anatomical and physiological adaptations aimed at supporting fetal growth and development while preparing for labor and delivery. These changes affect multiple organ systems and contribute to the successful progression of pregnancy until childbirth.[1]

The anatomical and physiological changes associated with pregnancy can affect a woman's ability to perform daily activities. Progressive increases in fetal, placental, and amniotic fluid weight throughout gestation result in substantial changes in body mass distribution, leading to shifts in the center of mass (COM) and center of pressure (COP), which are key determinants of postural stability. To compensate for these changes and maintain balance, pregnant women develop adaptive postural and movement strategies that alter normal biomechanical patterns and help minimize the risk of falls.[2] Drabiscakova et al. (2022) reported that the incidence of falls during pregnancy ranges from 13% to 29%.[3] The progressive increase in abdominal load during pregnancy places additional mechanical demands on the musculoskeletal system. Consequently, adaptations in the alignment of weight-bearing skeletal structures occur to maintain postural stability and balance. These biomechanical changes may alter muscle activation patterns and increase the workload of specific muscle groups, thereby contributing to the development of musculoskeletal pain. Among these complaints, low back pain is particularly prevalent and can substantially interfere with daily activities. The prevalence of pregnancy-related low back pain has been reported to affect approximately 50% of women during the first trimester, 40%–70% during the second trimester, and 70%–80% during the third trimester.[4]

Therefore, understanding the anatomical adaptations associated with pregnancy and their biomechanical consequences is crucial for optimizing maternal health and safety. These adaptations can influence posture, balance, and movement patterns, thereby affecting fall risk and the occurrence of musculoskeletal discomfort. Improved knowledge of these changes may facilitate the development of targeted preventive strategies and exercise programs that enable pregnant women to maintain functional independence and perform daily activities safely. The aim of this literature review is to examine the anatomical changes occurring during pregnancy and to evaluate their effects on maternal biomechanics, particularly posture, balance, and movement patterns, with an emphasis on their relationship to fall risk and preventive interventions.

Postur

The human vertebral column is characterized by physiological curvatures that contribute to postural stability and efficient load distribution. These include the cervical and lumbar lordoses, which are convex anteriorly, and the thoracic and sacral kyphoses, which are convex posteriorly. Anatomically, the vertebral column is composed of 33 vertebrae and measures approximately 60 cm in length in young adult females. The relative contribution of each vertebral region to overall body height has been estimated at approximately 8% for the cervical spine, 20% for the thoracic spine, 12% for the lumbar spine, and 8% for the sacrococcygeal region.[5]

Pregnancy is associated with progressive alterations in spinal curvature. Studies have demonstrated a significant increase in thoracic kyphosis during the second and third trimesters compared with non-pregnant women. Likewise, lumbar lordosis becomes significantly more pronounced during the third trimester, reflecting biomechanical adaptations to the anterior displacement of body mass associated with fetal growth.[6]

The increasing mass of the gravid uterus imposes additional loading on the lumbar musculature and alters the distribution of body weight. To maintain balance and prevent forward displacement of the center of mass, pregnant women commonly compensate by leaning the trunk posteriorly. Consequently, hyperextension of the trunk and pelvis becomes more pronounced as pregnancy progresses, with reported increases of approximately 112% between the first and second trimesters and an additional 61% between the second and third trimesters.[7]

Compensatory hyperextension during pregnancy occurs not only at the pelvis but also at the knee joint, contributing to the maintenance of anterior–posterior balance and upright trunk alignment. This altered knee posture increases strain on the anterior cruciate ligament (ACL), which may adapt through gradual elongation under sustained mechanical loading. Although such adaptations may facilitate postural compensation, excessive knee hyperextension can alter lower-limb biomechanics and adversely affect postural stability and balance regulation.[8]

Pregnancy-related low back pain is a prevalent musculoskeletal condition that can significantly impair functional capacity and quality of life. It may develop at any stage of pregnancy, with its prevalence generally increasing as gestation progresses. Previous studies have reported that approximately 50% of women experience low back pain during the first trimester, 40%–70% during the second trimester, and 70%–80% during the third trimester. The progressive increase in prevalence throughout pregnancy supports the notion that low back pain arises from cumulative musculoskeletal and biomechanical adaptations, including alterations in posture, anterior displacement of the center of mass (COM), increased lumbar loading, and greater mechanical demands on the erector spinae musculature associated with fetal growth and weight gain.[9]

Balance

Under normal conditions, the body's center of mass (COM) is situated slightly to the second sacral vertebra (S2), providing an optimal position for maintaining postural stability. Pregnancy induces substantial changes in body mass distribution as the fetus, placenta, and amniotic fluid progressively increase in size and weight. As a result, the COM of the upper body shifts anteriorly and inferiorly, whereas the pelvic COM moves anteriorly and superiorly.[10] These changes alter the alignment of the body relative to its base of support and challenge postural control mechanisms, necessitating adaptive strategies to preserve balance and prevent falls.[11] The anterior displacement of the center of mass (COM) in the sagittal plane is associated with increased anterior–posterior postural sway, which has been reported to persist for as long as two months after childbirth. To counteract the progressive anterior shift in body mass distribution and the increasing mechanical load associated with advancing gestation, pregnant women develop an increased lumbar lordotic curvature. This postural adaptation serves to maintain equilibrium and enhance COM stability within the anterior–posterior plane.[12]

Postural balance is maintained through the coordinated integration of multiple sensory systems. Although the vestibular system plays a crucial role in balance regulation, sensory inputs from the visual, haptic, and proprioceptive systems are also essential. The central nervous system continuously processes and integrates information from these sources to preserve postural stability and ensure effective motor control during static and dynamic activities.[13]

Sancar et al. (2020) demonstrated that women in the third trimester exhibited significantly higher LOS test values than those in the first trimester, reflecting a diminished capacity to control the displacement of the center of mass within the base of support. Furthermore, evaluation using the modified clinical test of sensory interaction in balance (mCTSIB) revealed significantly poorer balance performance in the third trimester compared with the first and second trimesters during testing with the eyes closed on a firm surface. These results suggest that the biomechanical and sensory adaptations associated with advancing pregnancy adversely affect postural control, particularly under conditions in which visual feedback is unavailable.[11]

Consistent with these observations, Oliveira et al. (2009) assessed postural balance through stabilometry and compared pregnant and non-pregnant women. Their results revealed a significant increase in the COP displacement radius among pregnant women during eyes-closed testing while standing with a self-selected abducted foot position. The increased COP excursion indicates impaired postural stability and greater body sway, reflecting the challenges imposed by pregnancy-related changes in body mass distribution and sensory integration.[14]

Several studies have demonstrated that visual dependence for postural control increases with advancing gestational age, suggesting a compensatory shift in sensory weighting to maintain balance in response to pregnancy-related changes in the musculoskeletal and proprioceptive systems.[2,12,14] The ability to maintain postural balance in pregnant women decreases progressively as gestation advances and may remain impaired for approximately 6–8 weeks after delivery. This decline in postural stability is associated with an elevated risk of falls, reflecting pregnancy-related alterations in musculoskeletal alignment, sensory integration, and neuromuscular control.[12,15]

The Effects of Hormonal Changes on Posture

Beyond the mechanical effects of increased body mass on posture and balance, pregnancy-related hormonal changes also significantly influence the musculoskeletal system. Levels of relaxin, estrogen, and progesterone are elevated during pregnancy. Relaxin, a member of the insulin-like peptide family, is primarily secreted by the corpus luteum and consists of two disulfide-linked chains with a molecular weight of approximately 6 kDa. During pregnancy, additional production occurs in the decidua and placenta under the stimulation of human chorionic gonadotropin (hCG). Relaxin enhances collagenase activity, resulting in collagen degradation and subsequent remodeling of connective tissue structures.[16]

The mechanical loading imposed by the enlarging uterus, in combination with elevated levels of relaxin and progesterone, contributes to an increase in the anteroposterior dimensions of the pelvis. This reflects ligamentous laxity and connective tissue remodeling associated with pregnancy-related hormonal changes.[17,18]

Increased laxity of both the anterior and posterior pelvic joints is observed during pregnancy. Progressive stretching of the rectus abdominis muscle leads to a relative inferior positioning of the anterior pelvis, which in turn contributes to an increased anterior pelvic tilt. Alterations in pelvic morphology during pregnancy represent physiological adaptations that support fetal development and facilitate labor and delivery. Following childbirth, pelvic alignment progressively returns toward its pre-pregnancy condition, typically within approximately one month postpartum.[18]

Estrogen is a steroid hormone involved in the regulation of the female reproductive system and the development of secondary sexual characteristics. It is mainly synthesized in the ovaries. Serum estrogen concentrations fluctuate throughout the menstrual cycle and rise markedly during pregnancy, reaching levels up to 1,000 times higher than those observed in non-pregnant women. [19] Lee et al. (2015) reported that ligaments exposed to high estrogen concentrations demonstrate decreased activity of lysyl oxidase (LOX), a fibroblast-derived enzyme essential for collagen cross-linking in ligamentous structures. A decrease in LOX activity contributes to reduced ligament stiffness and increased laxity, thereby weakening the mechanical stability of ligamentous structures.[20] In pregnancy, the combined effects of increased body mass and ligamentous laxity at the knee joint further promote knee hyperextension, potentially altering lower-limb biomechanics and postural control.[8]

Locomotor pattern

Pregnancy is associated with significant physical and hormonal adaptations, including increased body mass, anterior displacement of the center of mass (COM), and neuromusculoskeletal alterations. These changes affect postural stability and balance control, particularly during dynamic activities such as locomotion. In the third trimester, pregnant women exhibit a significant reduction in gait speed compared with non-pregnant individuals.[21–23] Bertuit et al. reported that women in the third trimester of pregnancy demonstrated a 22% reduction in walking speed compared with non-pregnant controls. This reduction in gait speed was associated with increased body mass.[21]

Progressive widening of the pelvic girdle and increased anterior pelvic tilt are associated with a reduction in hip joint mobility, including flexion, extension, abduction, and adduction, accompanied by a compensatory increase in external rotation. These alterations serve to maintain balance during pregnancy but result in biomechanical changes in gait patterns. Specifically, reduced hip flexion and extension contribute to shorter step length, while decreased abduction and increased external rotation lead to a wider step width. These proximal changes further affect distal joint mechanics, with the talocrural joint exhibiting a tendency toward increased pronation during stance.[24]

Alterations in the talocrural joint position can significantly affect gait patterns, as these joint plays an important role in shock absorption during stepping, adaptation to uneven surfaces, and providing a stable base of support (BOS). Consequently, changes in talocrural joint mechanics may increase the risk of falls. Ersal et al. compared pregnant women with a history of falls and those without. Their findings showed that pregnant women without a history of falls exhibited an 18% increase in talocrural joint stiffness and a 25% increase in hip (coxal) joint stiffness compared with those who had experienced falls.[25]

In addition to the pelvic and knee joints, ligamentous laxity may also occur in the plantar aponeurosis, a key structure of the foot that contributes to the formation of the medial longitudinal arch. Weakening of the plantar aponeurosis, together with increased body weight during pregnancy, can lead to a reduction in the height of the foot arch and an increased contact area between the sole of the foot and the ground, a condition known as flat foot (pes planus). Flat foot may contribute to pain and discomfort not only in the general population but also among pregnant women.[26]

Pregnant women exhibit a significant reduction in step length during walking compared with non-pregnant women. This decrease in step length is accompanied by a reduction in cadence.[22,23] In addition, an increase in step width is commonly observed, resulting in a wider distance between the feet. This adaptation serves to enlarge the base of support (BOS) and thereby enhance postural stability and balance control.[23,27]

The gait cycle consists of two primary phases: the stance phase, during which the foot remains in contact with the ground and supports body weight, and the swing phase, during which the foot is lifted off the ground and advances forward. The stance phase begins with heel strike and ends with toe-off, accounting for approximately 60% of the gait cycle. The swing phase begins at toe-off and ends when the heel of the same foot contacts the ground again, comprising the remaining 40% of the gait cycle. Throughout these phases, coordinated flexion and extension movements occur at the major joints of the lower extremities, including the hip, knee, and talocrural joints. Mei et al. reported that pregnant women demonstrate a reduced peak hip flexion angle during the stance phase of walking. A similar reduction in maximal joint angle was also observed at the talocrural joint. They further reported that anterior pelvic tilt was significantly greater in women during the third trimester than in those during the second trimester and in non-pregnant women. Furthermore, the hip joint exhibited increased external rotation in pregnant women relative to non-pregnant controls.[24]

Contrary to the observations of Mei et al., Li et al. reported increased peak flexion and extension angles at the hip, knee, and talocrural joints during the stance phase of walking. Nevertheless, the overall joint range of motion was found to be significantly decreased. This apparent discrepancy suggests that although the joints may reach greater peak positions at certain points during gait, the total angular excursion throughout the movement cycle is diminished. Reduced joint range of motion may adversely affect gait parameters, particularly step length and walking speed.[28] As gestational age advances, pregnant women exhibit a reduction in step length and walking speed, accompanied by increases in step width, stance phase duration, and double-support time.[22,24,28]

During normal gait, knee extension is primarily achieved through the contraction of the quadriceps femoris muscles. In pregnant women, however, the contribution of the quadriceps femoris appears to be relatively reduced, with the gluteal muscles assuming a greater role in facilitating lower-limb support and movement, despite not directly crossing the knee joint. This alteration in muscle activation patterns is attributed to the increased mass and volume of the uterus and fetus, which promote anterior pelvic tilt. The resulting change in pelvic alignment may place the quadriceps femoris at a mechanical disadvantage, thereby reducing its ability to generate force efficiently. Consequently, greater reliance on the gluteal musculature may occur as a compensatory adaptation to maintain functional gait and postural stability during pregnancy.[28]

Fall Risk

Pregnant women have a reported fall risk ranging from 13% to 29%. The incidence of falls during pregnancy is comparable to that observed among women over 65 years of age. Among pregnant women who experience falls, approximately 9.7% report falling more than twice during the course of their pregnancy.[29] Gestational age has been shown to correlate with measures of postural stability and fall risk. Women in the third trimester exhibit significantly poorer stability indices and higher fall-risk scores compared with non-pregnant women. These findings suggest that the progressive biomechanical and physiological adaptations associated with advancing pregnancy contribute to impaired balance control and an increased likelihood of falls.[30]

Progressive weight gain throughout pregnancy can impair postural balance and increase the risk of falls. In addition to body weight, increases in abdominal circumference also appear to influence fall risk. Takeda et al. (2018) reported that pregnant women who had experienced falls exhibited a 9.9% increase in abdominal circumference from the second to the third trimester, whereas those without a history of falls showed an increase of only 6.9%. Increases in abdominal circumference and body weight contribute to an anterior displacement of the center of mass (COM). Furthermore, the presence of increased anterior pelvic tilt may limit the functional capacity of the hip flexor muscles, thereby compromising the ability of the pelvic and femoral musculature to stabilize posture effectively. As a result, postural control may be impaired, leading to a greater susceptibility to falls during pregnancy.[31]

Drabiscakova et al. (2022) sought to identify determinants of fall risk among pregnant women by comparing individuals with a history of falls to those without such a history. Several demographic and clinical parameters were examined, including maternal age, height, body mass index (BMI), parity, and serum vitamin D concentration. Among these variables, maternal age emerged as the only statistically significant predictor of fall risk. In contrast, height, BMI, parity, and vitamin D levels showed no significant association with fall occurrence. The findings indicate that increasing maternal age may contribute to a heightened susceptibility to falls during pregnancy.[3]

Interventions for Improving Postural Alignment and Balance

Several studies have evaluated interventions that may help pregnant women reduce fall risk associated with impaired balance and alleviate pregnancy-related pain. Pharmacological therapies and invasive procedures are generally reserved for situations with strong clinical indications because of the potential risks they may pose to fetal development. Non-pharmacological approaches, including proprioceptive training, lumbar stretching and stabilization exercises, and postural correction, have been proposed as effective strategies for reducing fall risk and mitigating musculoskeletal pain during pregnancy.[32–35]

El-Shamy et al. evaluated a group of pregnant women who received education and supervised proprioceptive training for four weeks and compared them with a control group. The proprioceptive exercises were performed according to the Cox® Proprioception Training Program and included activities such as single-leg standing, tandem walking, and exercises using a stability ball. The balance parameters evaluated included the anterior–posterior stability index, medial–lateral stability index, and overall postural stability index. Comparison between the two groups revealed a significant reduction in balance index scores among women who participated in the proprioceptive training program. Because lower stability index values indicate better postural control, these findings suggest that pregnant women who performed proprioceptive exercises demonstrated superior balance compared with those in the control group.[32]

The additional load on the anterior aspect of the body and the anterior displacement of the center of mass (COM) increase the mechanical stress placed on the lumbar musculature. A study conducted by Fontana Carvalho et al. in Canada in 2020 concluded that lumbar stabilization and stretching exercises significantly reduced pain and improved postural balance in pregnant women after a six-week intervention period. Furthermore, electromyographic (EMG) assessments demonstrated increased activation of the external oblique abdominal muscle following the exercise program.[33]

Postural changes during pregnancy may contribute to pain in various regions of the body. The lower back and pelvic regions are among the most commonly affected areas due to pregnancy-related postural deviations. Strengthening and balance exercises are therefore important interventions for reducing these musculoskeletal complaints. In addition, maintaining proper posture during standing, sitting, walking, and other daily activities is essential to minimize excessive mechanical stress on specific muscle groups and promote optimal musculoskeletal function throughout pregnancy.[34]

In addition to exercise-based interventions, several studies have investigated the use of external supportive devices to enhance physical support and postural stability during pregnancy. Cakmak et al. evaluated the use of a maternity support belt (MSB) in pregnant women and concluded that it may improve postural balance and reduce the risk of falls.[35]

Another study conducted by Chamnankrom et al. examined the application of elastic therapeutic tape to the lumbar region (Figure 2.15). The authors reported that the tape reduced low back pain by 29.4% immediately after application and by 75.4% after one week of use. Furthermore, the use of elastic taping was associated with improvements in walking speed compared with placebo.[36]

Conclusion

Pregnancy induces anatomical, hormonal, and biomechanical changes that alter posture, balance, and gait. Increased abdominal load, anterior displacement of the center of mass, and pregnancy-related ligamentous laxity contribute to postural adaptations, reduced stability, and an increased risk of falls and musculoskeletal pain. Advancing gestational age, maternal age, weight gain, and abdominal enlargement further increase fall risk. Interventions such as proprioceptive training, lumbar stabilization exercises, postural education, and supportive devices may help improve balance, reduce pain, and decrease the risk of falls during pregnancy.

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