Are Gait Parameters Changeable during pregnancy?

Salwa M. El Badry, PT.D* and Ahmed M. EL-Halwagy, M.D**
*Department of Physical Therapy for Gynaecology and Obstetrics, Faculty of Physical Therapy, Cairo University.
**Department of Gynaecology and Obstetrics, Faculty of Medicine, Cairo University.

ABSTRACT

This study was conducted to measure deviations that may occur in gait at the 1st, 2nd and 3rd trimesters of normal pregnancy. Thirty pregnant women at their first trimester were selected from Obstetrics outpatient clinic, at Kasr El-Aini University Hospital. They were evaluated at their 1st, 2nd and 3rd trimesters of pregnancy by Qualysis Gait Analysis System to detect deviations that may occur in kinematics and kinetics gait parameters including pelvic motion in the transverse, coronal and sagittal planes as well as, ground reaction force (GRF) in the antero-posterior and vertical directions. Results showed a statistically highly significant ($P<0.001$) increase in anterior pelvic tilting, downward pelvic drop, vertical acceleration of body's C.O.G and a significant ($P<0.05$) increase in the 2nd peak. Also, results revealed a highly significant ($P<0.001$) decrease in upward pelvic rise as well as, a significant ($P<0.05$)decrease in backward pelvic rotation. While, braking force and the 1st peak of GRF showed non-significant change ($P>0.05$). So, it could be concluded that changes in pelvic motion during pregnancy affect stability of the pelvis and increase stress on the lumbo-sacral area. As well as, the increased forward propulsion of GRF may be responsible also, about the increased tendency of falling forward which is commonly observed during pregnancy.
Key words: *Pregnancy, Gait, Pelvis, Ground reaction force, Motion analysis.*

INTRODUCTION

Gait is a functional task requiring complex interaction and coordination among most of the major joints of the body, particularly those of the lower extremity[5]. It is the outcome of a complex interactions between many neuromuscular and structural elements of the locomotor system[29].

Gait cycle consists of two phases for each limb, stance and swing, which is more or less symmetrical with regard to angular motion of the major joints, muscle activity, as well as weight bearing on the lower extremities, as a result, it will be efficient in translating the body's center of mass all over the locomotion[5].

The major determinants of gait were originally identified by Saunders et al.,[27] as functions occurring during normal gait. They describe the human locomotion as the translation of the body's COG through space. The displacement of the COG is about two inches vertically and two inches horizontally during forward progression. They assert that abrupt changes in direction of the locomotive movement compel a high expenditure of energy. Thus, these gait determinants smooth out the pathway of the COG and limit the vertical and lateral displacements to an excursion of only two inches.

The first determinant of gait is pelvic rotation that represents the way in which the pelvis twists about a vertical axis during the gait cycle bringing the hip joint forwards as the hip flexes, and backwards as it extends. This means that for a given stride length, less flexion and extension of the hip is required, since a proportion of the stride length comes from the forward and backward movement of the hip joint rather than the angular movement of the leg. This reduction in the range of hip flexion and extension leads to a reduction in vertical displacement of the trunk[29].

Pelvic obliquity is the second element in which the pelvis drops slightly on the side of swing limb to lower the COG and contribute to the effectiveness of the abductor mechanism by producing relative abduction of the swing limb[15]. This pelvic obliquity decrease the vertical movement of the trunk by two to four mm[13].

The third element is knee flexion in stance phase in which knee flexes at heel strike and again at heel off. As the femur passes from flexion of the hip into extension, the hip joint would rise and fall if the leg remained straight. However, the flexion of the knee shortens the leg in the middle of this movement, reducing the height of the apex of the curve. So, this third determinant of gait smoothes the transition between the swing and stance phases, flattens out COG shifts, and increases shock absorption of GRF[15] thus, reducing the vertical displacement of the trunk during the gait cycle by a few mm.[14].

While, ankle dorsiflexion during stance phase constitutes the fourth determinant of gait. It is the movement of tibia over the foot during the foot flat to midstance and from midstance to heel off. That movement lowers the COG and propels the body forward[26].

The fifth element of gait is foot attachment to the distal segment that minimizes deviations of the knee from horizontal plane during stance phase. This is achieved by ankle joint planter flexion and dorsiflexion as well as, a subtaler joint pronation and supination, which provide relative shortening and lengthening of the supporting limb throughout the stance phase. Dorsiflexion and pronation effectively shorten the limb, and planter flexion as well as, supination lengthen[10] the limb. This element has a considerable role in raising the height of the COG when it is at its lowest position, thus reducing vertical displacement of the COG[20].

And, the sixth element is lateral trunk displacement in which the body is shifted over the weight-bearing leg with each step, there is a total lateral displacement of the body from side to side of approximately 4 to 5 cm with each complete stride. The presence of tibiofemoral angle and the stride width permit the tibia to remain vertical and the feet relatively close together. So, it prevents the need for horizontal excursion[10].

However, the six determinants of gait, in combination, contribute to the process of the normal gait. Deviations, or absence, of these movements undoubtedly results in gait disturbance of various magnitudes. These gait disturbances may be manifested in abnormalities of the stance and swing phases, alterations of the velocity of gait, and increased energy cost of walking. So, these factors have been thought to be important in rehabilitation practice and description of abnormal gait[25].

Pregnancy is a normal physiological state that is characterized by extensive biochemical, physiological and structural changes to provide a suitable environement for nutrition, growth and development of the fetus as well as, to prepare the mother for the process of parturition[4]. The body undergoes many musculoskeletal and postural changes due to weight gain and shift of the COG. in addition to hormonal and body mass distribution changes[16].

During the first trimester, major physiological changes are taking place even though maternal body changes are few. As pregnancy progresses, blood volume expands and the uterus continues to enlarge. Weight gain is ranged from zero to ten pounds. While, the second and third trimesters are accomplished by dramatic changes in a woman's body. Normal weight gain ranges between 22 and 35 pounds and is centered on the abdomen and pelvis, which alters both posture and COG so that changes in weight distribution occur and balance as well as, coordination may be affected[4].

So, the increased weight in pregnancy may significantly increase the forces across joints such as the hips and knees as much as 100% during weight bearing. Such large forces may cause discomfort and damage or at least instability of the joints[3].

During pregnancy, there is more posterior head position; cervical spine become hyperextended, lumbar lordosis increased and sagittal pelvic tilt is also, increased as women progressed from the first trimester to the third trimester. Progressively increasing anterior convexity of the lumbar spine which is a compensatory mechanism to keep the woman's COG over the leg, because the enlarging uterus could otherwise shifts the COG quite anteriorly[1,12].

Also, during pregnancy, woman's body release many hormones. One of these is relaxin, which purposely reduces ligament tension. This hormone has the effect of relaxing or loosening the ligaments and allowing more movement of the structures (joints) to which they are connected[9]. Joint laxity, in lumbar spine, is most notable in the anterior and posterior longitudinal ligaments, which support back. When this static support become lax, they can't effectively withstand shear forces. As pregnancy progress, the relaxin hormone allows pelvic expansion to accommodate the enlarging uterus; the joint laxity is more dominant in symphysis pubis and sacroiliac joints. Relaxation of these joints coupled with the increased lordosis and protuberant abdomen also, leads to unsteadiness of gait so, trauma from falls is more common during pregnancy than any other time in women life[12]. As well as, the walking gait of pregnant woman has been known as a waddling gait[18].

The pregnant woman has a different pattern of gait[23]. The waddling gait is characterized with increased obliquity of the pelvis, base of support, and angle of progression[11].

For gait analysis, different measuring techniques had been used. The data of human gait is captured to obtain all required data necessary for evaluating the quality of the subject's gait, as basic gait parameters (stride length, cadence and velocity), forces and moments occurring in the joints, muscle activity during each gait cycle, as well as, velocity and acceleration of each segment of the limb[22].

Three-dimentional system is used to permit simultaneous measurement of sagittal, coronal and transverse motion of trunk, pelvis, hip, knee and ankle. Measurement of these kinematics variables describe the effects of the combined forces acting on the subject and the ability to maintain erect posture and control smooth forward progression. Simultaneous measurement of rotations occurring at each segment enable the examiner to observe individual kinematics variables or combined patterns of motion that are difficult to be assessed visually[19].

There are two different types of optoelectronic systems used for quantitative gait evaluation active and passive markers systems. The advantage of an active marker system is that the computer knows in advance which markers are automatically identified. However, the illuminators require power; thus, multiple wires connected to a power source need to be attached to the patient which tend to interfere with the patient gait. In contrast, passive marker system require only a small infrared piece of material be placed over specific anatomic landmarks and a computer software program that determines the position of each marker automatically. So, passive marker system has become the preferred system for clinical practices, as it doesn't interfere with the patient gait[21].

The use of more than one camera is required, because one camera cannot visualize a marker during limb rotation or because another limb segment gets in the way. Each camera used in a 3-D analysis records markers positions in two dimensions. These markers are attached to the subject on specific landmarks. The X-Y-Z conversion of these data from two-dimensional (2-D) data into 3-D data is done by combining data from all cameras mathematically[17].

Despite the obvious visible changes in gait and posture during pregnancy, as well as, the suggested link between these changes and the development of postural symptoms[6]. However, a review of literature revealed no studies documenting walking kinematics and kinetics of the pregnant women. So, the purpose of this study was to assess the changes in kinematics (pelvic motion) and kinetics parameters (ground reaction force) of gait for normal pregnant women at their three different trimesters to provide quantitative overview about deviations of their gait.

SUBJECTS, INSTRUMENTS AND METHODS

Subjects

Thirty normal pregnant women at their first trimester (12 weeks' gestation) participated in this study. They were selected from the Obstetrics outpatient clinic, at Kasr El-Aini University Hospital. Their age ranged from 20 to 28 years old (23.30±2.50yrs), while their height ranged from 158 to 164cms (160.74±1.69 cms) and their weight ranged from 60 to 69 Kgs (63.17±2.59 Kgs), 64 to 74 Kgs (67.22±2.45 Kgs) and 65 to 74 Kgs (70.96±3.14 Kgs) at their 1st, 2nd and 3rd trimesters respectively.

Women with diabetes, pre-eclampsia, varicose veins, twins, L.B.P., sacroiliac joint pain, symphyseal pain, deformities and/or previous surgery at their back and lower limbs were excluded from this study.

Gestational age of each pregnant woman participated in this study was detected and calculated before the beginning of this study by ultrasonography.

Informed consent form had been signed from each normal pregnant woman before starting the study. Evaluation of each pregnant woman was conducted at 1st (12 weeks' gestation), 2nd (24 weeks' gestation) and 3rd (36 weeks' gestation) trimesters, in the Motion Analysis Laboratory at Faculty of Physical Therapy.

Instrumentations

1- Recording data sheet: All data and information of each pregnant woman participating in this study were recorded in a recording sheet.
2- Weight-height scale was used to measure the height and weight of each pregnant woman in this study.
3- Ultrasonographic machine was used before the starting of this study to calculate the gestational age of each pregnant woman as well as, to detect and exclude congenital anomalies.
4- Qualysis Gait Analysis System was used to measure and record the gait parameters of each pregnant woman, it consists of the following units:

a- ProReflex motion capture unit (MCU) 120: This unit is composed of a camera system having six cameras. The basic principle is to expose reflective markers to infra-red light and to detect the light reflected by the markers. The two dimensional (2-D) image of the markers are processed by the MCU and the 2-D coordinates of each markers are output as a data steam. Then, the 2-D data from the six cameras are combined for calculating the 3-D position of the markers. All cameras have capture capability of 120 frames/seconds, type: 170120, 100-240 V (50-60 Hz), 20 W (max. 230 mA).

b- A wand-kit is used for the calibration of the system: type 130440. The wand kit consists of two parts, L-shape part and another T-shape part.

c- A personal computer (PC) serial interface adapter is a communication cords which must be mounted in the PC.

d- A personal computer with the Q Trac and the Q Gait software installed: It has the following specifications:(1) system Microsoft windows 98, 2nd Ed., 4.10.2222A, (2) Registered to: Medical Eng. System Co., 16201- OEM- 0094512-06975, and (3) Manufactured and supported by crest computer, BE, Genuinelntel, X 86 Family 6, Model 8 stepping 6, 127.0 MBRAM.

Procedures

- A full history was taken from each pregnant woman before starting this study at 1st trimester (12 weeks' gestation).
- The height was measured before starting the study while, the weight was measured 3 times in the (1st, 2nd and 3rd trimesters).
- Each pregnant woman was instructed carefully about the evaluative procedures and she was advised to evacuate her bladder and wear thin fitted clothes before starting the measurement procedures.
- The measurement procedures followed the scheme below:

1- *System Calibration:*

At the start, L-shape wand was placed in the middle of the walkway at the force plate form with the x-axis in the walkway direction And then, T-shape wand was moved in x, y and z directions, so that, the wand markers were oriented in all three directions of the measurement volume. During this procedure, the operator moved around in the measurement volume to allow all cameras to view L-shape and T- shape of the wand during the calibration. Then, the operator move the wand in the suggested area of measurement as much as possible, so that, all cameras connected to the system can pick up the marker position in various locations, then four reference markers were placed at force plate corners to measure force plate position, after that the data was captured, tracked and then exported.

2- *Measurement of force plate position:*

Four reference markers were placed at force plate corners to measure force plate position, The data was captured, tracked and then exported. This measurement took a few minutes.

3- *Application of markers:*

For each pregnant woman, 20 reflecting dots (markers), according to the system software were placed on special bony landmarks of her body. Two markers were placed on the tip of both acromions, one marker at the 12th thoracic vertebra and another one on the sacrum. Two markers were placed on both anterior superior iliac spines (ASIS), others on both greater trochanters, on the superior surface of the patellae on both sides, over the knee joint line on both sides, over the tibial tuberosities on both sides, over both lateral malleolli, over the dorsum of both feet between bases of the second and third metatarsal bones and two markers one for each heel (posterior of calcanus) at the same horizontal plane as the toe marker.

4- *First trial to adjust walking pathway:*

Each pregnant woman was instructed carefully about the evaluative procedures and she was advised to wear thin fitted clothes as well as, to evacuate her bladder before starting the measurement procedures.

Each woman tried out a suitable gait path before starting the measurements to get a sufficient and high quality data in the measurement. It was considered that each woman must start from a position away enough from the measurement volume to reach a natural continuous walking pattern once she entered the measurement volume.

To normalize the data with respect to the gait cycle, an entire gait cycle was captured within the volume (the data required for an entire gait cycle was from the first initial contact of one foot to the second toe off of the other foot).

5- *The Q Trac capturing image:*

Once the appropriate walking pathway was determined, it was the time for actual measurements. When the pregnant woman passed the starting position, the Q trac measurement was started and she was let to continue walking until several meters after the volume to allow the Q trac measurement to be completed.

The pregnant woman hit the force plate with one foot at a time and the therapist made sure that she did not make any target on force plate.

At the end of capturing, the mother sat down and all markers were removed from her body. These procedures were repeated again for each pregnant woman of this study in the 2nd (24 weeks' gestation) and 3rd trimesters (36 weeks' gestation).

6- *Data Processing and Editing:*

The data was processed and edited in Q trac before it was used in the Q gait software as follows:

- Tracking of the motion data (creating 3-D marker trajectories).
- Sorting of the 3-D according to the markers used in the measurements.
- Selection of an appropriate part of the data and export of this selection.

7- *Calculation and Results:*

By using the Q gait software, automatically the following gait parameters and their graphs were determined:

A- Pelvic motion:
- Obliquity (lateral tilting)of the pelvis at early stance phase and late at push off.
- Peak anterior tilting of the pelvis.
- Rotation of the pelvis at heel strike, which represented forward rotation, and its peak at the end of the stance phase which represented backward rotation of the pelvis.

B- Ground reaction force:
- Antero-posterior GRF.
- Vertical GRF.

Statistical analysis

- Descriptive statistical analysis was used for the collected data to calculate mean, standard deviation (S.D), percentage, and student t-test.
- Differential statistical analysis was used in the form of ANOVA and correlation tests (Pearson) to correlate variables with each other.

RESULTS

A- Pelvic motion

Obliquity(Upward and downward lateral tilt) of the pelvis:

As observed in table (1) and Fig. (1) ,the upward lateral tilt of the pelvis ranged from (0.50° to 8.50°), (-1.30° to 7.80°) and (-2.90° to 5.60°), with mean values of 4.93 ±2.30°, 3.76 ±2.73° and 1.64 ±2.67° respectively in the 1st, 2nd and 3rd trimesters of normal pregnancy.

The percentage of differences between the 1st and either 2nd or 3rd trimesters of normal pregnancy were equal to 23.73%, 66.67% and 56.38% respectively. These changes were found to be statistically non-significant (P>0.05) between the 1st and 2nd trimesters. While, the changes were found to be statistically highly significant (P<0.01) decreased between the 1st and 3rd trimesters as well as, between the 2nd and 3rd trimesters.

And, according to the downward lateral pelvic tilting, it was ranged from (0° to 6°), (1° to 7°) and (1.4° to 9°), with mean values of 2.65±1.89°, 3.79 ±2.32° and 5.47±2.43° respectively in the 1st, 2nd and 3rd trimesters of normal pregnancy.

The percentage of differences between the1st and either 2nd or 3rd trimesters of normal pregnancy were equal to 43%, 106.41% and 44.34% respectively. These changes were found to be statistically significant (P<0.05) and (P<0.01) increased between the 1st and 2nd as well as, between the 2nd and 3rd trimesters respectively while, between the 1st and 3rd trimesters, the changes were found to be statistically highly significant increased (P<0.001).

Table (1): The Mean values of upward and downward lateral pelvic tilting of the normal pregnant women in the 1st, 2nd and 3rd trimesters.

	Upward lateral tilt of the pelvis			Downward lateral tilt of the pelvis		
	1st trimester	2nd trimester	3rd trimester	1st trimester	2nd trimester	3rd trimester
Mean	4.93°	3.76°	1.64°	2.65°	3.79°	5.47°
S.D.	±2.30	±2.73	±2.67	±1.89	±2.32	±2.43
% of change and P-value	1st–2nd trimesters	23.73%	>0.05	---------	43%	<0.05
	2nd–3rd trimesters	56.38%	<0.01	---------	44.34%	<0.01
	1st–3rd trimesters	66.67%	<0.001	---------	106.41%	<0.001

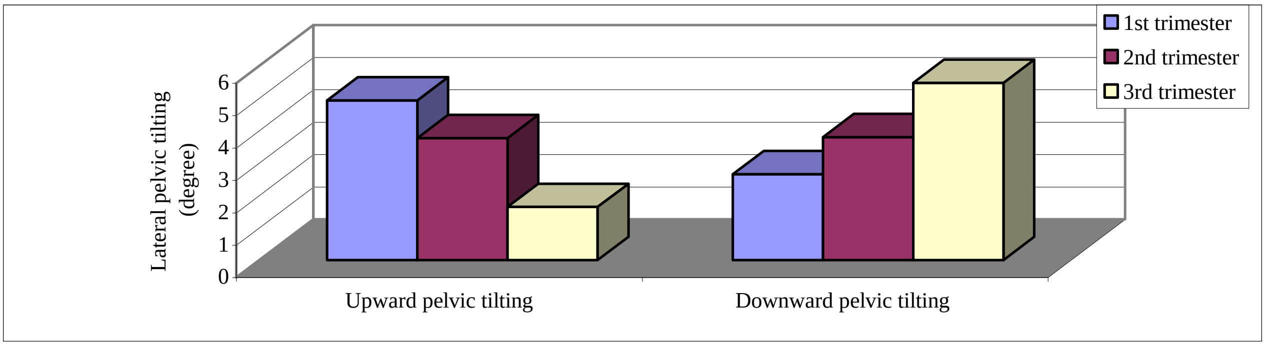

Fig. (1): The Mean values of upward and downward lateral pelvic tilting of the normal pregnant women in the 1st, 2nd and 3rd trimesters.

Anterior tilting of the pelvis

The anterior pelvic tilting ranged from (2.50° to 16°), (6° to 18°) and (8.60° to 22°), with mean values of 7.27 ±3.32°, 9.83 ±3.43° and 13.37 ±4.32° in the 1st, 2nd and 3rd trimesters of normal pregnancy respectively.

The percentage of differences between the 1st and either 2nd or 3rd trimesters of normal pregnancy were 35.21%, 83.91% and 36.01% respectively. These changes were found to be statistically significant (P<0.01) increased between the 1st and 2nd trimesters while, between the 1st and 3rd trimesters as well as, between the 2nd and 3rd trimesters, the changes were found to be statistically highly significant (P<0.001)increased as shown in table (2) and Fig. (2).

Table (2): The Mean values of anterior pelvic tilting of the normal pregnant women in the 1st, 2nd and 3rd trimesters.

	Anterior tilting of the pelvis		
	1st trimester	2nd trimester	3rd trimester
Mean	7.27°	9.83°	13.37°
S.D.	±3.32	±3.43	±4.32
% of change and P-value	1st–2nd trimesters	35.12%	<0.01
	2nd–3rd trimesters	36.01%	<0.001
	1st–3rd trimesters	83.91%	<0.001

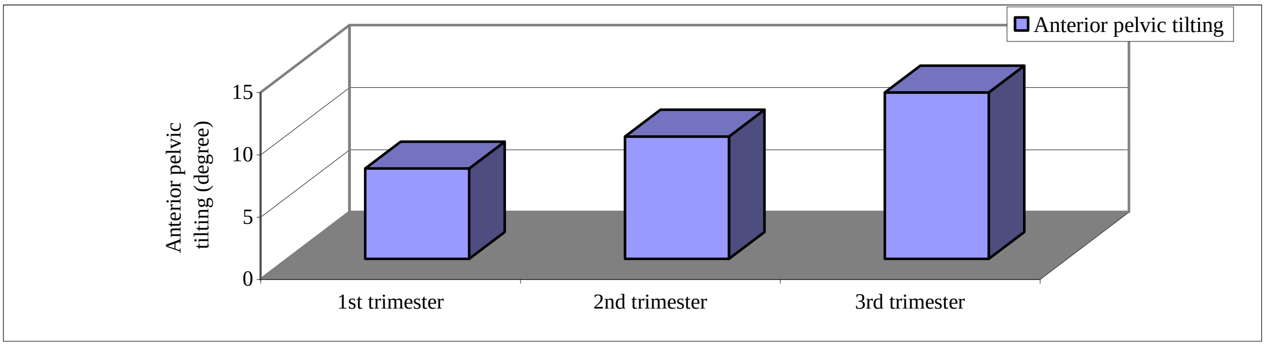

Fig. (2): The Mean values of anterior pelvic tilting of the normal pregnant women in the 1st, 2nd and 3rd trimesters.

Rotation of the pelvis (forward and backward):

The forward pelvic rotation ranged from (0.50° to 8.70°), (0.50° to 10°) and (-1.90° to 6.70°), with mean values of 4.25 ±2.45°, 5.66 ±2.51° and 4.11 ±2.13° respectively in the 1st, 2nd and 3rd trimesters of normal pregnancy.

The percentage of differences between the 1st and either 2nd and 3rd trimesters of normal pregnancy were equal to 33.18%, 27.39% and 3.29% respectively. These changes were found to be statistically significant (P<0.05) increased between the 1st and 2nd trimesters and significant (P<0.05) decreased between the 2nd and 3rd trimesters, while between the 1st and 3rd trimesters, the difference was found to be statistically non-significant (P>0.05).

While, The backward pelvic rotation ranged from (2.60° to 11°), (0° to 9.40°) and (-2° to 8°), with mean values of 5.60 ±2.67°, 3.75 ±2.95° and 3.67 ±2.97° in the 1st, 2nd and 3rd trimesters of normal pregnancy respectively.

The percentage of differences between the 1st and either 2nd or 3rd trimesters were equal to 33.04%, 36.70% and 2.13% respectively. These changes were found to be statistically significant (P<0.05) decreased between the 1st and 2nd trimesters as well as, between the1st and 3rd trimesters. While, the difference between the 2nd and 3rd trimesters, was found to be statistically non-significant (P>0.05) as shown in table (3) and Fig. (3).

Table (3): The Mean values of pelvic rotation of the normal pregnant women in the 1st , 2nd and 3rd trimesters.

	Forward rotation of the pelvis			Backward rotation of the pelvis		
	1st trimester	2nd trimester	3rd trimester	1st trimester	2nd trimester	3rd trimester
Mean	4.25°	5.66°	4.11°	5.60°	3.75°	3.67°
S.D.	±2.45	±2.51	±2.13	±2.67	±2.95	±2.97
% of change and P-value	1st–2nd trimesters	33.18%	<0.05	---------	33.04%	<0.05
	2nd–3rd trimesters	3.29%	<0.05	---------	2.13	>0.05
	1st–3rd trimesters	27.39%	>0.05	---------	36.70%	<0.05

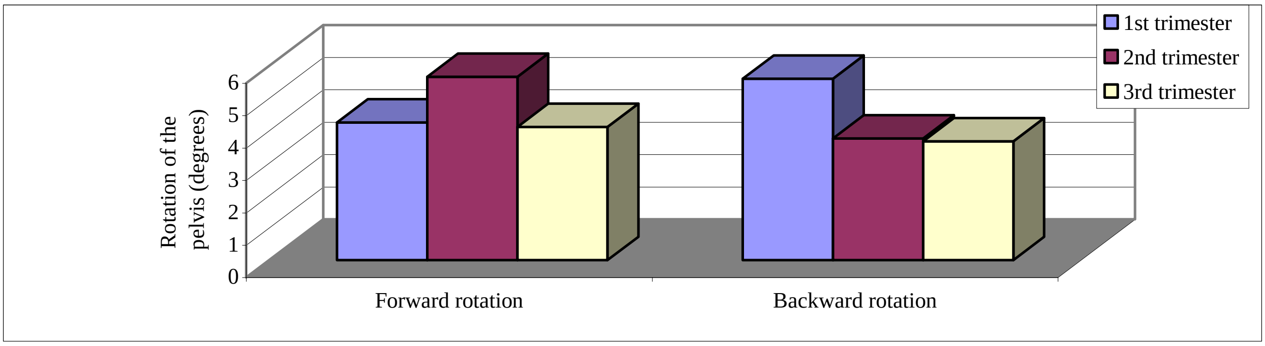

Fig. (3): The Mean values of pelvic rotation of the normal pregnant women in the 1st , 2nd and 3rd trimesters.

B- Ground Reaction Force (GRF):

Anterior-posterior ground reaction force:

The braking force of the GRF ranged from (8.70 to 15.50%), (8 to 15%) and (8 to 15%) of total B.W., with mean values of 12.32 ±1.88, 12.24 ±2.14 and 11.35 ±2.08% of total B.W. in the 1st, 2nd and 3rd trimesters of normal pregnancy respectively.

The percentage of differences between the 1st and either 2nd or 3rd trimesters of normal pregnancy were equal to 0.65%, 7.90% and 7.30% respectively. These changes were found to be statistically non-significant (P>0.05) between the 1st and 2nd trimesters, also between the 1st and 3rd trimesters as well as, between the 2nd and 3rd trimesters.

While, The forward propulsion of the GRF ranged from (13.5 to 17.4%), (12.5 to 20.8%) and (14 to 19 %) of total B.W., with mean values of 15.18 ±1.07, 16.69 ±2.47 and 16.58 ±1.47% of total B.W. in the 1st, 2nd and 3rd trimesters of normal pregnancy respectively.

The percentage of differences between the 1st and either 2nd or 3rd trimesters of normal pregnancy were equal to 9.95%, 9.22% and 0.006% respectively. These changes were found to be statistically significant increased (P<0.01) and (P<0.05) between the1st and 2nd trimesters as well as, between the 1st and 3rd trimesters respectively while, between the 2nd and 3rd trimesters, the difference was statistically non-significant (P>0.05), as shown in table (4) and Fig. (4).

Table (4): The Mean values of antero-posterior GRF for the normal pregnant women in the 1st, 2nd and 3rd trimesters.

	Braking force of GRF (% of total Body Weight)			Forward propulsion of GRF (% of total Body Weight)		
	1st trimester	2nd trimester	3rd trimester	1st trimester	2nd trimester	3rd trimester
Mean	12.32°	12.24°	11.35°	15.18°	16.69°	16.58°
S.D.	±1.88	±2.14	±2.08	±1.07	±2.47	±1.47
% of change and P-value	1st–2nd trimesters	0.65%	> 0.05	---------	9.95%	<0.01
	2nd–3rd trimesters	7.30%	> 0.05	---------	0.006%	>0.05
	1st–3rd trimesters	7.90%	> 0.05	---------	9.22%	<0.05

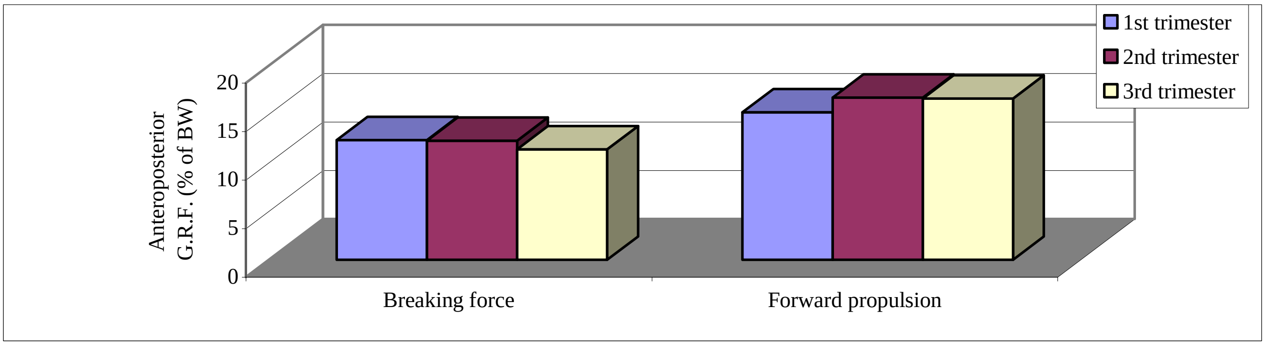

Fig. (4): The Mean values of antero-posterior GRF for the normal pregnant women in the 1st, 2nd and 3rd trimesters.

Vertical Ground Reaction Force:

The first peak of the vertical GRF ranged from (90 to 107.80%), (84.40 to 112.90%) and (87 to 110.50%) of total B.W., with mean values of 95.61 ±3.95, 98.39 ±6.77 and 99.72 ±6.47% of total B.W. in the 1st, 2nd and 3rd trimesters of normal pregnancy respectively.

The percentage of differences between the 1st and either 2nd or 3rd trimesters of normal pregnancy were equal to 2.90%, 4.30% and 1.35% respectively. These changes were found to be statistically non- significant (P<0.06) between the 1st and 2nd, also between the 1st and 3rd trimesters as well as, between the 2nd and 3rd trimesters of normal pregnancy.

While, the second peak of the vertical GRF ranged from (88% to 107%), (89.5% to 118%) and (90.8 to 112.5%) of total B.W., with mean values of 96.77 ±5.30, 103.29 ±7.98 and 103.44 ±6.22% of total B.W. in the 1st, 2nd and 3rd trimesters respectively of the normal pregnancy.

The percentage of differences between the 1st and either 2nd or 3rd trimesters of normal pregnancy, were equal to 6.74%, 6.89% and 0.001% respectively. These changes were found to be statistically significant (P<0.01) between the 1st and 2nd, also, between the 1st and 3rd trimesters. While, between the 2nd and 3rd trimesters, the difference was found to be statistically non-significant (P>0.05), as shown in table (5) and Fig. (5).

Table (5): The Mean values of 1st and 2nd peaks of vertical GRF of the normal pregnant women in the 1st, 2nd and 3rd trimesters.

	1st peak of vertical GRF (% of total Body Weight)			2nd peak of vertical GRF (% of total Body Weight)		
	1st trimester	2nd trimester	3rd trimester	1st trimester	2nd trimester	3rd trimester
Mean	95.61	98.39	99.72	96.77	103.29	103.44
S.D.	±3.95	±6.77	±6.47	±5.30	±7.98	±6.22
% of change and P-value	1st–2nd trimesters	2.90%	<0.06	----------	6.74%	< 0.01
	2nd–3rd trimesters	1.35%	<0.06	----------	0.001%	> 0.05
	1st–3rd trimesters	4.30%	<0.06	----------	6.89%	< 0.01

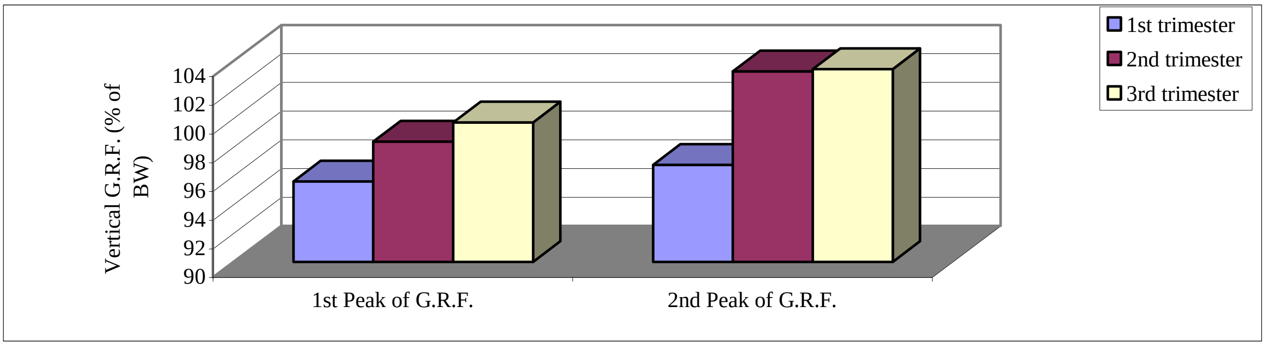

Fig. (5): The Mean values of 1st and 2nd peaks of vertical GRF of the normal pregnant women in the 1st, 2nd and 3rd trimesters.

DISCUSSION

Despite of the obvious visible changes in gait as well as, posture that occur during pregnancy, and the suggested link between these changes and the development of postural symptoms, few studies have been conducted to specifically investigate the biomechanical changes of the pregnant gait[6].

Recording changes in gait parameters of the pregnant woman in the three trimesters may be predictors to pain; fatigue signs and falling that are sometimes expressed by the pregnant women.

Therefore, such study may provide information for physical therapists who deal with the pregnant women to propose advise, recommend antenatal exercises and postural adaptation that may reduce such signs and allow the pregnant woman to have a happy pregnancy with minimal complaints.

The results of this study revealed a statistically significant increase in the downward lateral pelvic tilting (pelvic drop) between the 1st and 2nd as well as, between the 2nd and 3rd trimesters while, between the 1st and 3rd trimesters, the changes were found to be statistically highly significant increased.

The increased pelvic drop (downward lateral pelvic tilt) of the pregnant women in the present study can be attributed to the increased hip adduction range over the stance limb during pregnancy. This was supported by studies of several authors. Simoneau[28], reported that the drop of the pelvis at push off in normal subjects is a consequence of the pelvis-on-femoral hip adduction of the other stance hip. Also, Russek[26], mentioned in his report about the abnormal adult gait patterns that one of causes for increased drop of the pelvis was increased hip adduction range of motion. Also, Foti et al.,[11] supported this finding as they found increased hip adduction range of motion in the 3rd trimester of pregnancy.

In addition, the significant increase in the downward descent of the pelvis during motion can be attributed to the increased width of the pelvis of the pregnant women, which was essential to accommodate growth and parturition of the fetus, that comes in consistent with the study of Colliton[8] ,who reported that the joint laxity, which is prominent in the symphysis pubis and sacroiliac joints, permits symphysis pubis to widen from 0.5 mm to a maximum of approximately 12 mm which in turn increase width of the pelvis resulting in more movements of the structures connected to these joints. Also, the increased pelvic drop of the pregnant women in the present study can be attributed to the increased hip adduction range as well as, reduced the activity of the hip abductor muscles over the stance limb during pregnancy and, this was supported by the studies of several authors[11,26&28].

While, the significant decrease in the upward tilt of the pelvis occurring early in the stance phase in the 2nd and 3rd trimesters can be attributed to the growth of the fetus as the anterior and lateral expansion may obstruct the rise of the pelvis upward during walking. This come in agreement with Colliton[8], who reported that the gravid uterus expands out of the pelvis after 12 weeks gestation and moves superiorly, anteriorly and laterally.

In the present study, there was a statistically significant increase in the anterior pelvic tilting between the 1st and 2nd trimesters while, between the 1st and 3rd trimesters as well as, between the 2nd and 3rd trimesters, the changes were found to be statistically highly significant increased.

The significant increase in the anterior pelvic tilting during pregnancy can be attributed to both the increased mass of the abdomen located in the anterior lower part of the trunk as reported by Artal et al.,[4] and Ostgaard et al.,[24] also, the increased moment arm which represents the distance between the center of motion of the spine and the center of gravity of forward abdominal mass. This increase in mass and moment arm produce high forward moment which resulting in the increase of anterior pelvic tilting during pregnancy[7].

The increase in the mass located in the lower anterior area of the trunk associated with increased forward movement of ground reaction force produce forward moment, which tends to rotate the pelvis forward. These explain the finding of significant increase in the forward rotation of the pelvis between 1st and 2nd trimesters in the present study, while, the engagement of the presenting part of the fetus, which commonly occurs in the last month of pregnancy, explains the significant decrease in the forward rotation in the 3rd trimester of normal pregnancy in this study.

The significant decrease in the backward rotation of the pelvis during pregnancy in the present study can be attributed to weakness of the abdominal muscles, which occurred during pregnancy as reported by Perry[25] , who mentioned that abdominal muscles work alone, or with the hamstring muscles to produce backward rotation of the pelvis. Also, the deceased backward rotation observed in this study is due to limited movement of the hip extension. This findings is supported by Foti et al.,[11] who reported a decrease in maximum hip extension during pregnancy.

And, the significant increase in the vertical acceleration of the COG in the current study comes in agreement with Anderson and Pandy[2]. They reported that the muscles which are responsible for forward acceleration of COG were planter flexors of the contralateral leg and dorsi flexors of the ipsilateral and then by combined actions of the gluteus maximus, medius as well as minimus of the ipsilateral leg. So, any increase in the activity of these muscles can lead to increase upward acceleration of COG. Also, this finding was supported by Foti et al.,[11] as they reported increased activity of the planter flexors, hip extensors and abductors muscles during pregnancy.

In the present study, there is a significant increase in the 2nd peak of vertical ground reaction force between the three trimesters of pregnancy, which can be attributed to higher activity of the ankle planter flexors to provide propulsion that needed to initiate the new step, as the pregnant woman is in need of more propulsion and more vertical acceleration of the body segment due to increase abdominal mass during pregnancy. This explanation is supported by the study of Anderson and Pandy[2].

Finally, the results of the present study revealed a significant changes in the females' pelvic motion during pregnancy as well as, increase ground reaction forces.

REFERENCES

1- Adrian, J. and Cooper, M.: Biomechanics of human movement, 2nd ed., WCB Brown & Benchmark, London, 21-41, 1995.
2- Anderson, F. and Pandy, M.: "Individual muscle contributions to support normal walking", Gait and Posture, 1-11, 2002.
3- Artal, R., Clappe, J. and Vigil, D.: "Exercise during pregnancy", WWW. American College of Sports Medicine.Com., 1-3, 2000.
4- Artal, R. and Toole, M.: "Exercises in pregnancy: Guidelines of the American college of obstetricians and gynecologists for exercise during pregnancy and the post partum period", Br J Sport Med, 37: 6-12, 2003.
5- Barr, A. and Backus, S.: Biomechanics of gait; In: Nordin, M.; Frankel, H. and Legar, D.(eds.): Basic biomechanics of the musculoskeletal system, 3rd Ed., Lippincott William & Wilkins, Philadelphia, 439-457, 2001.
6- Bird, R., Menz, B.and Hyde, C.: "The effect of pregnancy on foot print parameters", J Am Pediatr Med Assoc, 89(8): 405-409, 1999.
7- Chao, E. and Cahalan, T.: Kinematics and kinetics of normal gait; In: Simdt, G. (ed.): Gait in rehabilitation, 1st Ed., Churchll Livingstone, New York, 1-19, 1990.
8- Colliton, J.: "Back pain and pregnancy: Active management strategies", Physician and Sports Medecine, 24(7): 1-8, 1996.
9- Donovan, D. and VanMetter, B.: "Chiropractice care during pregnancy", WWW. Savanna Chiropractice. Com., 1-3, 2002.
10- Epler, M.: Gait; In: Richardson, K. and Iglarsh, Z. (eds.): Clinical orthopaedic physical therapy, W.B. Saunders Company, Philadelphia, 602-625, 1994.
11- Foti, T., Bagely, A. and David, J.: "Biomechanical alterations in gait during pregnancy", Presented at the 21st annual meeting of the American Society of Biomechanics, Clemson, South Carolina, 1-3, 1997.
12- Gabbe, G., Nieble, R. and Simpsom, L.: Obstetrics normal and problem pregnancies, 3rd ed., Illustrated by Mikki Senkarik, New York, 91-109, 1996.
13- Gard, S. and Childress, D.: "The effect of pelvic tilt on the vertical displacement of trunk during normal walking", Gait and Posture, 5: 233-238, 1997 (Abst).
14- Gard, S. and Childress, D.: "The influence of stance-phase knee flexion on the vertical displacement of the trunk during normal walking", Arch. Phys. Med. Rehabil., 80(1): 26-32, 1999.
15- Giallonardo, L.: Gait; In: Myers, R. (ed.): Saunders manual of physical therapy practice, 1st Ed., W.B Saunders Company, Philadelphia, 1105-1119, 1995.

16- Hamilton, N. and Luttgens, K.: Kinesiology: Scientific basis of human motion, 10th ed., Mc Graw Hill, Boston, 537-551, 2002.
17- Heckman, J. and Sassard, R.: "Changes in the extremities", WWW. Socialbirth. Org., 1-3, 1994.
18- Girard, S.: "Postural changes in pregnancy", WWW. Pregnancy. Com., 1-3, 2002.
19- Johanson, M.: Gait laboratory: structure and data gathering; In: Rose, J. and Gamble, J. (eds); Human walking, 2nd Ed., Williams & Wilkins, Philadelphia, 203-224, 1994.
20- Kerrigan, D., Marciello, M. and Rieley, P.: "A refined view of the determinants of gait: Significance", Arch. Phys. Med Rehabil., 81(8): 1077-1080, 2000.
21- Kerrigan, D., Schaufele, M. and Wen, M.: Gait analysis; In: Delisa, J. and Gans, B.(eds); Rehabilitation medicine principle and practice, 3rd Ed., Lippincott-Raven, Philadelphia, 167-187, 1998.
22- Kocsis, L.: "More precise measurement method for gait analysis", WWW. Bjkmf. Hu., 1-15, 2002.
23- Nyska, M., Softer, D., Porat, A., Howard, C. and Meizner, I.: "Planter foot pressure in pregnant woman", Isr. J. Med. Sci., 33(2): 139-146, 1997 (Abst).
24- Ostgaard, H., Anderson, G. and Schultz, A.: "Influence of some biomechanical factors on low back pain in pregnancy", Spine, 18: 61-65, 1993.
25- Perry, J.: Gait analysis, normal and pathological function, 1st Ed., Slack inc Thorofare, NJ, London, 9-13, 1992.
26- Russek, L.: Closed kinematic chain and gait; In: Donatelli, R. (ed.): The biomechanics of the foot and the ankle, 2nd Ed., FA Davis Company, Philadelphia, 90-123,1996.
27- Saunders, J., Inman, V. and Eberhart, H.: "The major determinants in normal and pathological gait", Am. J. Bone Joint Surg., 35: 543-558, 1953.
28- Simoneau, G.: kinesiology of walking; In: Neumann, D. (ed.): Kinesiology of the musculoskeletal system: foundation for physical rehabilitation, Mosby Company, London, 523-569, 2002.
29- Whittle, W.: Gait analysis: An introduction, 1st Ed., Bulterworth-Heinemann, Oxford, 48-90, 1991.

الملخص العربي

هل هناك تغيرات في قياسات المِشية لدى السيدات أثناء الحمل؟

تهدف هذه الدراسة إلي قياس التغيرات في قياسات المِشيةِ لدى السيدات في المراحل المختلفة من الحمل الطبيعي وذلك من خلال التحليل الحركي في الثلث الأول والثاني والثالث من الحمل . وقد تم قياس بعض العوامل الكينماتيكية والكيناتيكية التي تحتوي علي حركة الحوض في الاتجاهات الرأسية والأمامية والمستعرضة و قوة رد فعل الأرض في الاتجاهات الأفقية والرأسية، وقد أجريت هذه الدراسة على ثلاثين سيدة حامل في الثلث الأول من الحمل الطبيعي تم اختيارهن من العيادة الخارجية بمستشفي القصر العيني الجامعي وقد تم تقييم جميع السيدات باستخدام جهاز التحليل الحركي للمِشيه . أوضحت النتائج وجود زيادة ذات دلالة إحصائية عالية في الميل الأمامي والميل السفلي الجانبي للحوض . وكذلك وجود زيادة ذات دلالة إحصائية في قوة رد فعل الأرض الأفقية الأمامية والقمة الثانية لقوة رد فعل الأرض الرأسية. كما أظهرت النتائج وجود نقص ذي دلالة إحصائية عالية في الميل العلوي الجانبي ونقص ذي دلالة إحصائية في الدوران الخلفي للحوض. بينما لم يوجد أي تغير في قوة رد فعل الأرض الأفقية الخلفية والقمة الأولى لقوة رد فعل الأرض الرأسية. ومن ذلك يمكن استنتاج أن الاختلافات في حركة الحوض أثناء الحمل تؤثر على اتزانه وتزيد من العبء على المنطقة القطنية العجزية. كما أنها قد تؤدى إلى زيادة احتمال الوقوع إلى الأمام نتيجة لزيادة قوة رد فعل الأرض الأفقية الأمامية .

الكلمات الدالة : الحمل – المِشيه – الحوض – قوة رد فعل الأرض – التحليل الحركي .