Faculty Of physical Therapy
Cairo University

Cairo University

Kinematic Description of Fetal Lower Limbs Movements in theThree Trimesters of Pregnancy

***Hend Mohamed Aly[1], Prof. Dr. Eman Ibrahim El-Hadidy[2], PhD, and Dr. ManalRadwnSalim[3], PTD.**

1. Head of Physical Therapy Unit at FawzyMoaaz Governmental Hospital, Alexandria, Egypt.
2. Professor in the Department of Growth and Developmental Disorders in Children and its Surgery, Faculty of Physical Therapy, Cairo University.
3. Fellow of Physical Therapy, Pediatric Specialized Hospital (Abu El-Rish). Cairo University Hospitals.

ABSTRACT

Background: Very little is known about fetal movements in utero during pregnancy. Despite these movements are crucial to normal musculoskeletal development. Purpose: To describe kinematically normal fetal lower limbs movements in three trimesters of pregnancy. Study design: cross sectional study. Subjects: Forty five healthy fetuses were diagnosed by obstetrician. They were assigned into three equal groups (A, B &C); according to trimesters of pregnancy (1st,2nd,and 3rd) respectively. Methods: fetuses were scanned in their mothers' wombs via four dimensional cine ultrasound devices. Kinematic analysis was done for hip, knee and ankle including instantaneous angular positions, joint ranges and velocity parameters for the three groups. AutoCAD program was used to measure the angles. The results of this study showed that there were some of developmental variability in knee and ankle tested parameters which can be explained by the consistency of hip joint parameters among the three trimesters of pregnancy. Conclusion: Kinematic analysis of fetal lower limbs' movements may reflect the processes of motor development for fetuses among three trimesters of pregnancy.Key words: Fetal movements, Movement patterns, kinematic analysis, Lower Limbs.

INTRODUCTION

Fetal movements in uterus are normal part of fetal development. They play an important role in normal musculoskeletal development.[(1)] Fetal movements have been studied extensively. [(2, 3)] However only a gross interpretation of a crude trace of patterns indicates which particular types of movements has been provided. Little is known about how fetal movements are planned and executed in various stages of fetal development[(4)] It has been found that fetal movement can be a significant indicator of fetal health, with studies showing that decreased fetal movement may precede fetal demise/stillbirths. [5 ,6] Fetal behavior is assessed throughout direct observation of movements and activities of the fetus in utero with the use of ultrasound machine.[7]

Four dimensional ultrasound (4D) enables simultaneous visualization of the movements of fetal head, body, extremities in three dimensions in real time mode. Its development has provided new opportunities to study fetal movements and even embryonic behavior. And it enables the opportunity of simultaneous visualization of the movements of the head, body, and extremities in three dimensions, in a real-time mode.[8] In a relatively short period of time 4D ultrasound stimulated multicentre studies on fetal and embryonic behavior with more convincing imaging. [9]

The mechanical forces generated by fetal movements are important for prenatal musculoskeletal development and in particular joint shape. [10 , 11] A common example of abnormal joint shape in human babies is developmental dysplasia of the hip joint (DDH).[12]In it the movements of fetuses are restricted indicating that a link may exist between fetal movements and abnormal development. [13] A remarkable repertoire of fetal movements is revealed by ultrasound from as early as 7' & 12' weeks postmenstrual age (PMA). First movement is lateral bending of the head followed at 9' to 10' weeks by complex, coordinated, generalized movements of the head, trunk, and limbs, twitches, whole body movements, stretches, isolated limb movements, breathing movements, jaw movements (including yawning, sucking and swallowing) and hiccups by ten weeks of gestational age. [13, 14, 15] One problem with these previous studies has been the absence of a uniform definition of fetal movements and the inability to quantities movements objectively. There is considerable variance in the literature for quantification of the proportion of time that the fetus is active and the average number of movements per time segment, which has been suggested to be due to differences in study design, data analysis and varying definitions of what constitutes a single movement. [16 ,13]Kinematic analysis,a detailed descriptive analysis of movements,was presented as reliable mean to assess motor performance in fetuses. [17]

The purpose of this study was to kinematically analyze lower limbs movements of normal fetuses in the three trimesters of pregnancy delineating temporal and spatial qualities of movements.

SUBJECTS AND METHODS

This study was conducted under guidelines and the approval of ethical committee of the Faculty of Physical Therapy, Cairo University. The pregnant women signed a consent form authorizing their participation in this study. They were recruited from June 2014 to June 2015 from private clinics in the Governorate of Alexandria.

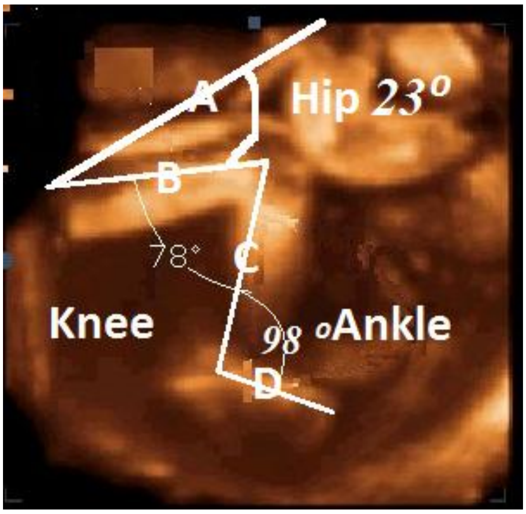
A total of forty five single fetuses in their mothers' womb were assessed by obstetrician and diagnosed as normal fetuses, Women's ages ranged from twenty to thirty-five years old and had good health, average amniotic fluid volume. Their fetuses had normal biophysical profile; fetuses' growth was symmetrical and average as compared with menstrual gestational age. We excluded pregnant women with preeclampsia, high blood pressure, diabetes. Fetuses were excluded if they had intrauterine growth restriction, polyhaydarminos, or chromosomal abnormalities. [18] In this study forty five fetuses were divided into three groups (A, B & C) according to trimesters of pregnancy (1^{st}, 2^{nd}, and 3^{rd})respectively. Each group had 15 fetuses; their ages were 12.04 ± 1.21 weeks, 21.45 ± 2.01 weeks and 30.69 ± 1.74 weeks respectively. The obstetrician scanned lower limbs movements of all fetuses in three groups using 4D ultrasound.

Ultrasound scanning procedures: scanning was done using 4D Cine ultrasound device (4D Volusone 730 Expert). It produces real-time three-dimensional ultrasound films with a rate of two frames per second. The scanned periods of fetal lower limbs movements equaled 29.91 ± 11.18 sec, 26.19 ± 9.59 sec & 25.62 ± 3.71 sec in groups A, B & C respectively. The pregnant women were instructed to have their last meal before scanning by two hours. **[18]** The examinations were conducted only in the evening.**[19]** Mothers rested for at least half an hour before the scan. They sat in comfortable recumbent positions during scanning.**[20]**The scanned films were recorded digitally to analyze fetuses' lower limbs movements by the researchers.

Kinematic analysis procedures:

The recorded films were processed using special program (Video to Jpeg converters). The program imported the film in full frame mode and exported two frames / second as a bitmap sequence {exporting one frame every half a second}. These sequenced frames (bitmap images) were imported to AutoCAD program. [17] -The AutoCAD program was originally used to generate graphics for designing and drafting through the use of computer. The program is able to calculate angles between drawn lines automatically. **[21 & 22]** The analyzed frames were 46 ± 14 frame, 42 ± 9 frame and 40 ± 12 frame) respectively for groups A, B and C respectively. The kinematic analysis included:

a) ***Instantaneous angular positions:*** Hips, knees, and ankles instantaneous angular positions were measured in each frame simultaneously. Hip instantaneous position is the anterior angle between trunk (longitudinal axis from iliac crest to tip of shoulder) and thigh segment (from the greater trochanter to lateral epicondyle). knee flexion/ extension instantaneous angular position was obtained by measuring backward angle between thigh segments and the leg segment (from lateral epicondyle to lateral malleolus), and ankle plantar flexion/ dorsi flexion instantaneous angular position was obtained by measuring anterior angle between leg segments and the foot segment (from lateral malleolus to base of little toe). as shown in fig.1



a- Trunk b-Thigh

c- Leg d- Foot

Fig.1 Hip , knee & ankle instantaneous joints angular positions in one frame for a fetus at 3rd trimester of pregnancy.

b) ***Time domain graph***: for each fetus participating in this study; the previously measured coinciding instantaneous hip, knee and ankle angular positions were listed in time domain graphs. For each tested joint (hip, knee and ankle) the curve showed peak/s (p) - The maximum value/s in the curve-. Valley/s (v) which is the lowest value/s in the curve. They are instants at which rate of change of angular positions have zero value [(23)] as shown in fig.2.

c) **Joints movements' ranges:** According to **Enoka (2008)**the descending curve in time domain graph means that hip, knee are moved in flexion direction and ankle is moved in dorsi flexion direction. While the ascending curve means hip, knee are moved in extension direction and ankle in planter flexion direction. [(23)] The estimated flexion / extension ranges of hip, knee and ankle dorsi /planter flexion are calculated by subtracting absolute valley values corresponding to Y axis from absolute peak values corresponding to Y axis. As shown in fig. 2.

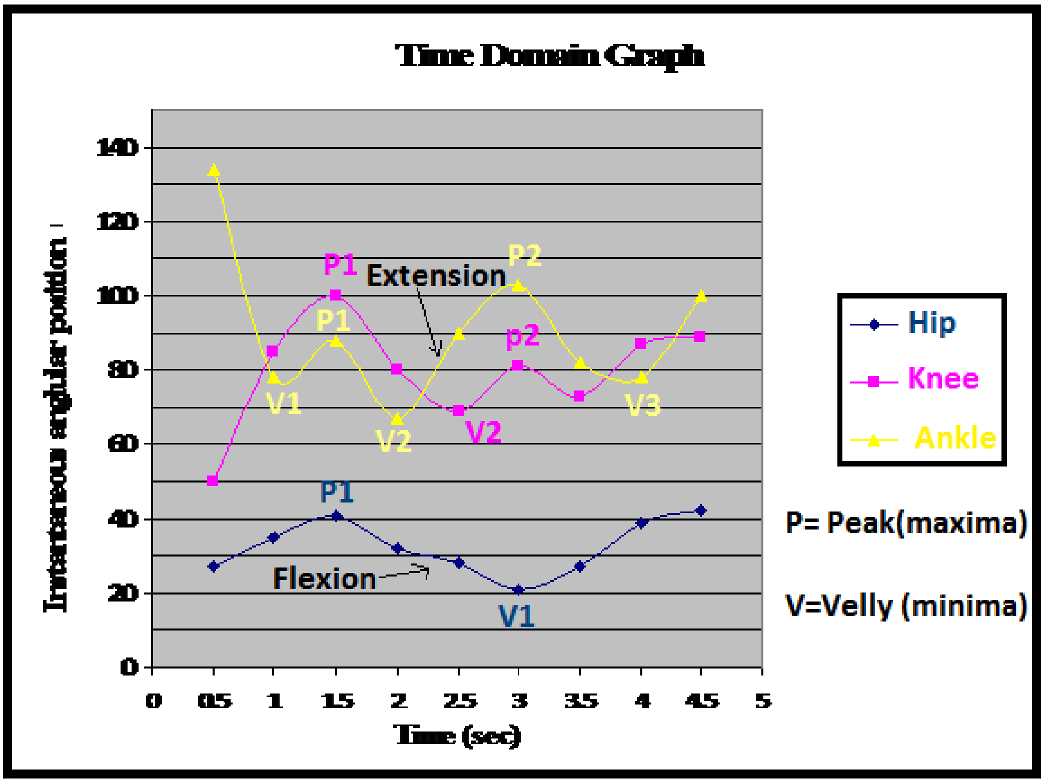


Figure (2): Time domain graph of hip, knee and ankle instantaneous angular positions.

d) **Angular velocity of joint** movements iscalculated by dividing the joint ranges (flexion / extension) of hips, knees and ankles (dorsi / planter flexion) / durations (subtracting absolute valley values (sec) corresponding to X axis from absolute peak values corresponding to X axis.[(23)]

Statistics:

The tested parameters (instantaneous angular joint positions, joints' ranges, and joints velocities) for hips, knees and ankles for each fetus were calculated by dividing the total resultant data / numbers (arithmetic average). Data were collected and statistically analyzed using statistical package for social sciences (SPSS) version 17 for windows. ANOVA test was used to compare results among groups (A, B and C). If among group comparisons proved statistically differences then Post Hoc multiple comparison tests was applied to detect source of variance. Statistical significance was assumed at a p value of <0.005. [(24)]

RESULTS

Demographic characteristics of fetuses are shown in table (1).

Table (1):Demographic characteristics of fetuses

Demographic characteristics	**A(1st trimester)**	**B (2nd trimester)**	**C (3rd trimester)**
	$\bar{X} \pm$ **SD**	$\bar{X} \pm$ **SD**	$\bar{X} \pm$ **SD**
Gestational age (last menstrual period) week	12.04 ± 1.21	21.45 ± 2.01	30.69 ± 1.74
Gestational age (ultrasound - Size wise) week	11.83 ± 1.96	20.58 ± 1.04	28.95 ± 2.33
Biparietal diameter (mm)	29.20 ± 7.42	53.77 ± 3.87	61.85 ± 4.17
Body weight (gm)	126.0 ± 58.83	539.7 ± 83.78	856.5 ± 297.7

In table (2) hip's instantaneous angular positions, hadn't any significant differences, so ANOVA post Hock test wasn't needed .While table (2) showed significant differences among studied groups for knee's instantaneous angular positions. So ANOVA post Hock test revealed that group A was significantly different from groups B and C at p values < 0.040 and 0.001 respectively. Also table (2) showed significant differences among studied groups for ankle's instantaneous angular positions. Those differences were : group C significantly different from groups A and B at p values < 0.035 and 0.010 respectively.

Tab. (2): **Comparing mean values of instantaneous angular joint positions among fetal groups (A, B and C).**

Instantaneous angular joint positions (°)	**Fetuses**			**ANOVA**	
	A (1st trimester)	**B** (2nd trimester)	**C** (3rd trimester)		
	$\bar{X} \pm$ **SD**	$\bar{X} \pm$ **SD**	$\bar{X} \pm$ **SD**	**f value**	**P**
Hip joint	62.30 ± 23.44	76.85 ± 12.04	79.65 ± 13.30	1.804	< 0.179
Knee Joint	114.86± 18.45	82.1 ± 34.64	93.41 ± 18.85	6.679	< 0.003
Ankle Joint	53.31 ± 13.87	64.04 ± 18.05	93.07 ± 23.15	3.93	< 0.028

In table (3) hip's flexion/extension ranges hadn't any significant differences, so ANOVA post Hock test wasn't needed .While table (3) showed significant differences among studied groups for knee's flexion/extension ranges. So ANOVA post Hock test revealed that group C was significantly different from groups A and B at p values < 0.035 and 0.010 (for flexion)/p value < 0.042 and 0.037(for extension) respectively. Also table (3) showed significant differences among studied groups for ankle's dorsiflexion ranges / planter flexion ranges. Those differences were: group A was significantly different from groups B and C at p values < 0.024 and < 0.003(for dorsiflexion) / p values < 0.001 and < 0.004(for plantar flexion) respectively.

Tab. (3): Comparing mean values of joint movement ranges among fetal groups (A, B and C).

Joint movement ranges (°)	Fetuses			ANOVA	
	A (1st trimester)	**B** (2^{nd} trimester)	**C** (3^{rd} trimester)		
	$\bar{X}$ ± SD	$\bar{X}$ ± SD	$\bar{X}$ ± SD	F Value	P Value
Hip Flexion	13.92 ± 7.50	10.80 ± 3.15	10.56 ± 2.90	1.91	0.161
Hip Extension	13.62 ± 5.76	11.28 ± 4.17	11.06 ± 4.17	0.81	0.451
Knee Flexion	13.82 ± 5.99	12.13 ± 5.70	8.34 ± 3.32	4.82	0.021
Knee Extension	11.40 ± 4.74	11.07 ± 5.63	8.09 ± 3.30	3.61	0.037
Ankle Dorsi Flexion	17.95 ± 7.69	12.87 ± 4.85	10.83 ± 3.92	5.17	0.010
Ankle Planter Flexion	19.88 ± 9.27	10.88 ± 5.08	10.79 ± 4.45	8.11	0.001

In table (4) hip's flexion/extension velocities hadn't any significant differences, so ANOVA post Hock test wasn't needed .While table (4) showed significant differences among studied groups for knee's flexion/extension velocities. So ANOVA post Hock test revealed that group C was significantly different from groups A and B at p values < 0.006 and < 0.013(for flexion) / p value < 0.004 and < 0.026(for extension) respectively. Also table (4) showed significant differences among studied groups for ankle's dorsiflexion ranges / planter flexion velocities. Those differences were: group A was significantly different from groups B and C at p values < 0.041, <0.034 (for dorsiflexion)/ p values < 0.046 and <0.024(for plantar flexion) respectively.

Tab. (4):Comparing mean values of values of joint movement velocities among fetal groups (A, B and C).

Average joint movement velocities (m/sec)	**A** (1st trimester)	**B** (2^{nd} trimester)	**C** (3^{rd} trimester)	ANOVA Test	
	$\bar{X}$ ± SD	$\bar{X}$ ± SD	$\bar{X}$ ± SD	F Value	P Value
Hip Flexion	16.50 ± 9.94	12.85 ±3.56	13.99 ±1.80	1.33	0.276
Hip Extension	16.90 ± 7.25	16.10 ± 4.14	14.22 ± 2.86	0.60	0.553
Knee Flexion	16.74 ± 8.09	15.04 ± 6.43	9.64 ± 4.15	5.10	0.011
Knee Extension	15.13 ± 5.11	13.23 ± 5.10	9.05 ± 2.89	4.93	0.018
Ankle Dorsi Flexion	23.57 ± 8.71	17.27 ± 7.30	14.60 ± 7.35	3.84	0.039
Ankle Planter Flexion	23.35 ± 09.17	16.15 ± 7.51	13.38 ± 6.91	4.21	0.030

DISCUSSION

There is evidence to suggest that there can be substantial variability in total movements and in the quantity of specific movement patterns between fetuses. As well there is lack of information on how variable the minimum and maximum ranges of movement frequencies are for healthy fetuses. [(13)]This is the first study to describe kinemetically the lower limb movements, with a specific measurable tool of assessment. Fetuses were assessed among the three pregnancy trimesters as spontaneous movements of one leg occur at 10' to 11' weeks post menstrual age (PMA). [(13, 14, 15)] Forty five fetuses were participated to this study, and divided into three groups according to their gestational age, one group for each trimester of pregnancy [(14)] Fetuses sex were excluded from the demographic criteria as previous studies mentioned that the number of leg movements weren't significant statistically between males and females.[(26)]

Four dimensional ultrasound (4D) was used to detect the fetuses' kicks as 4D ultrasound allows visualization of fetuses' movements two weeks earlier than 2D ultrasound. [(6, 27)]

The kinematic parameters used to describe the fetuses kicks were instantaneous angular positions, joints movements' ranges, and joints movements' velocities.

Those parameters were analyzed statistically by ANOVA test. While significant differences were found at the ANOVA analysis, a further ANOVA post hock analysis was needed to define whether the differences were between groups A & B, or between group A & C or between group B & C. [(24)]

By tracking joints' angles during fetuses' kicks, we noticed the differences in instantaneous angular positions, ranges, and average velocities of hip between fetuses groups weren't statistically different. That may be reflecting completion of hip movement development in the first trimester of pregnancy.

Knee instantaneous angular positions changed with a statistically significant differences among 1st, 2nd and 3rd trimesters of pregnancy. Knee instantaneous angular positions showed maximum flexion degrees of 114.86 ± 28.45 in 1st trimester of pregnancy, which was significantly different from knee instantaneous angular positions in 2nd and 3rd trimesters. In 2nd trimester knee instantaneous position decreased to a minimum flexion position of 82.1 ± 34.64 degrees. In 3rd trimester of pregnancy; the flexed instantaneous knees position 92.1 ± 28.85 degrees was higher than 2nd trimesters' instantaneous knees position, but with non significant differences were noted between both trimesters.

Knee flexion / extension ranges changed with a statistically significant differences among 1st, 2nd and

3rd trimesters of pregnancy. Knee flexion / extension ranges showed maximum flexion/extension ranges of 13.82 ± 5.99/ 11.40 ± 4.74 respectively in 1st trimester of pregnancy, which were significantly different from flexion / extension ranges in 3rd trimester that decreased into 8.34±3.32 / 8.09±3.30 respectively and were significantly different from flexion /extension ranges in 2nd trimester which were 12.13 ± 5.79 /11.07 ± 5.63 respectively .So significant differences in knee flexion/extension were shown between 1st and 3rd trimester, and between 2nd and 3rd trimester.

Knee flexion /extension velocities in 3rd trimester showed minimum values of 9.64 ± 4.15/ 9.05 ± 2.89 respectively , which was significantly different from 1st trimester knee flexion/ extension velocities (18.74 ± 9.09\ 15.13 ± 5.11) ; and significantly different from 2nd trimester knee flexion /extension velocities (15.04 ± 6.43/ 13.23 ± 5.10). With no significant differences between 1st and 2nd trimesters in knee flexion/extension velocities.

These results support that fetal movements decrease in frequency after the second trimester. But they contradict the same authors that their peaks weren't at the 2nd trimester except for the knee's instantaneous angular positions.[28, 29, 30, 1]

Ankles instantaneous angular positions changed with statistically significant differences among 1st, 2nd and 3rd trimesters of pregnancy. The 3rd trimester instantaneous angular positions of ankle joint showed maximum dosiflexion degrees of 93.07 ± 23.15 which was highly significantly different from 1st trimester's instantaneous angular positions which had a value of 53.31±3.87degrees. And with less extend significantly different from 2nd trimester of pregnancy which had a value of 64.04 ± 18.05 degrees. Finally non-significant differences were noted between 1st and 2nd trimesters.

While in ankle dorsi flexion / plantar flexion ranges the higher values were in the 1st trimester that reached 17.95 ± 7.69/ 19.88 ± 9.27 respectively. Those values are significantly different from 2nd trimester ankle dorsiflexion/plantar flexion ranges which were 12.87 ± 4.85/ 10.83 ± 5.08 respectively. And they were significantly different from 3rd trimester ankle dorsiflexion/plantar flexion ranges which were 10.83 ± 3.92/10.79 ± 4.45 respectively. Finally non-significant differences were found between 2nd and 3rd trimesters in ankle dorsiflexion/plantar flexion ranges.

As well the higher ankle dorsiflexion/ plantar flexion velocities were at the first trimester with values of 23.57 ± 8.71/ 23.35 ± 11.17 respectively. That meant significant differences between 1st trimester's ankle dorsiflexion/plantar flexion velocities and the 2nd trimester's ankle dorsiflexion/plantar flexion velocities which were 17.27 ± 7.30 / 16.15 ± 4.51 respectively; also significant differences between 1st trimester's ankle dorsiflexion/plantar flexion velocities and the 3rd trimester's ankle dorsiflexion/ flexion velocities which were 14.60 ± 7.35/13.38 ± 6.91 respectively. But differences between 2nd and 3rd trimesters' ankle dorsiflexion/plantar flexion velocities were non- significant.

These free moves of the ankle may be explained by the authors who clarify that beside the inherent neuromuscular function of the fetus, there are three major physical influences that have been shown to affect fetal movement; the amount of free intrauterine space, the amount and location of the amniotic fluid and fetal positioning. Free space not occupied by the fetus had available for movement depends on the volumes of womb, fetus and amniotic fluid. It has been suggested by them that the amniotic fluid distends the uterus, enabling the fetus to move without constriction as it grows [31]. Also confirmed by Nowlan (2015) who said that the mechanical environment experienced by the fetus affects its ability to move freely as the fetus moves in a dynamically changing constrained physical environment in which the freedom to move becomes increasingly restricted with increasing fetal size and decreasing amniotic fluid. [13]

By comparing joints' angles, a similarity was found in the statistic of the behavior of both joints: hip and ankle. As both had their highest values in their instantaneous angular positions at the 3rd trimester, while their lowest values of the same parameter were at the 1st trimester .Which may indicate spatial coincidence between hip and ankle joints but this still need further studies to be explained.

As a whole the three joints (hip, knee, and ankle) had been collected to have their highest values of their instantaneous angular ranges, and their angular velocities at the 1st trimester; and their lowest values of the same parameters at the 3rd trimester.

That could demonstrate that the fetuses lower limbs' move in a patterned manner with a temporal coincidence between its joints.

All previous results of hip, knee, and ankle movements' confirm the environmental and the biomechanical variables effects on early motor behavior. As well although the central nervous system sends preprogrammed patterns to different joints, but the different joints in the same limb show different movements' means due to different architecture, musculoskeletal characteristics of hip, knee and ankle.

Finally despite the relation between parameters values but there were many non-significant differences in-between them which means that not every apparent increase or decrease in the fetus' movement had real value , so all previous studies described fetus movement qualitatively or even relative quantification need to be reassessed.

Limitations to this study included unavailability of normative predictive values of fetal movement; it requires a significant amount of time to study fetal movement and to kinematically analyze movements' patterns, difficulty of recruiting the sample as mothers reused to participate in research work and 4D ultrasound is an expensive method of assessment. Future work will need to increase sample size, longtidunal study to express developmental patterns of fetal movements and to kinematically describe upper limbs and trunk movements of fetuses.

CONCLUSION

the values of this study could be a reparatoire for a part of the motor development in fetuses and a good indicator for early intervention.

REFERENCES

1. **Verbruggen S., Loo J., Hayat T., Hajnal J., Rutherford M., Phillips A. & Nowlan N.** (2015): "Modeling the biomechanics of fetal movements". Biomechanics and Modeling in Mechanobiology. November pp 1-10.
2. **Cioni G., Ferrari F., Einspieler C., Paolicelli P. B., Barbani M. T. and Prechtl H. F.**(1997):"Comparison between observation of spontaneous movements and neurologic examination in preterm infants" J. Pediatr. 130:704-11P.
3. **Jansson L., DiPietro.J, Elko A. (**2005): "fetal response to maternal methadone administration. Am. J. Obstet. Gynecol. 193: 611-617.
4. **Zoia S., Blason L., D'Ottavio G., Bulgheroni M., Pezzetta E., Scabar A. &Castiello U. (2007):** "Evidence of early development of action planning in the human fetus: a kinematic study". Exp Brain Res 176: 217-226.
5. **Efkarpidis S., Alexopoulos E., Kean L., Liu D. & Fay T.** (2004) Case-control study of factors associated with intrauterine fetal deaths. Med Gen Med 6: 53.
6. **Whitworth M., Fisher M., Heazell A.** (2011): Reduced fetal movements. Royal College of Obstetricians and Gynaecologists, London, Guideline 57.
7. **Yigiter A. &kavak N**. (2006): "normal stansards of fetal behavior assessed by 4dimensional sonography". J. Matern. Fetal Neonatal Med. 19:707-721.
8. **Kurjack A., Tikivica A., Stanjevic M., Mikovic B., Ahmed A., Azumendi G. & Carlo Di Renzo G.** (2008): "The assessment of fetal neurobehavior by three-dimensional and four-dimensional ultrasound" The Journal of Maternal-Fetal and Neonatal Medicine, October 2008; 21(10): 675–684
9. **Lebit F. &Vlareanu R.** (2011): "The Role of 4D Ultrasound in the Assessment of Fetal Behaviour". Mædica - a Journal of Clinical Medicine,, Volume 6 No.2, 120-127.
10. **Almli C., Ball R. & Wheeler M.** (2001): "Human fetal and neonatal movement patterns: Gender differences and fetal-to-neonatal continuity". Dev. Psychobiol. 38: 252-273.
11. **DiPietro J., Bronstein M., Costigan K., Pressman E., Hahn C., Painter K., Smith B., and Yi**

Lj). (2002. What does fetal movement predict about behavior during the first two years of life? DevPsychobiol 2002;40:358–371.

12. **Salihagic - Kadic A., Medic M., Kurjak A. (**2005): " 4Dsonography in the assessment of fetal functional neurodevelopment and behaviouralpaterns. Ultrasound Rev. Obstet. Gynecol.;5:115.
13. **Kahn J., Shwartz Y., Blitz E., Krief S., Sharir A., Breitel D., Rattenbach R., Relaix F., Maire P., Rountree R., Kingsley D. and Zelzer E.** (2009): "Muscle contraction is necessary to maintain joint progenitor cell fate. Dev Cell. 16: 734-743.
14. **Nowlan N. Chandaria V &, Sharpe J.** (2014): "Immobilized chicks as a model system for early-onset developmental dysplasia of the hip. J. Orthop. Res. 32: 777-785.
15. **Leck I.** (2000): "Congenital dislocation of the hip. Antenatal Neonatal Screen: Ed 2:398–424
16. **Nowlan N.** (2015): "Biomechanics of fetal movement". European Cells and Materials 29. 1-21
17. **De Vries J. & Fong B.** (2006): "Normal fetal motility: an overview". Ultrasound Obstet. Gynecol. 27: 701-711.
18. **Hart H.** (2006): "Fetal and infant movements and the young nervous system". Dev Med Child Neurol. Jul; 48 (7):547.
19. **Ten Hof J., Nijhuis I., Nijhuis J., Narayan H., Taylor D., Visser G. & Mulder E.** (1999):"Quantitative analysis of fetal general movements: methodological considerations. Early Hum Dev 56: 57-73.
20. **ManalR.Salim, Kamal E. Shoukry, Sherif D. Hussein and HanaaM.El-karaksy**(2004). **: "**Description of fetal and neonatal upper limb movement patterns" Unpublished thesis faculty of physical therapt, Cairo University.
21. **Kuno A., Akiyama M., Yamashiro C., Tanaka H., Yanagihara T. &Hata T.** (2001): "Three-dimensional Sonographic Assessment of Fetal Behavior in the Early Second Trimester of Pregnancy". J. Ultrasound Med. 20:1271–1275.
22. **Serón-Ferré M., Mendez N., Abarzua-Catalan L., Vilches L., Valenzuela F., Reynolds H., Llanos A., Rojas A., Valenzuela G. & Torres-Farfan A.** (2012): " Circadian rhythms in the fetus". Mol Cell Endocrinol. 5; 349(1):68-75.
23. **Lutz H. &Buscarini E.** (2011): "WHO manual of diagnostic ultrasound". Vol. 1. 2nd ed. Pages 1-175. Gutenberg Press Ltd. Malta. Review
24. **Vengoubal K.** (2001): "Engineering Drawing And Graphics + Autocad". Macmillan Publishing Company. New Age International Publisher. 4th ed. P. 23-44.
25. **Leach J. A.** (2015): "AutoCAD 2016 Instructor: a student guide for In –Depth coverage of AutoCad's Commands and features". SDC Puplications, USA. P. 6-43.
26. **Enoka R.** (2008): "Neuro-mechanics of human movement" 4th ed., Human kinetics. U. S. A.

P.451-453.

27. **Kirkwood B. & Sterne J. (**2003): "Essential medical statistics" 2nd edition Blackwell publishing.33-86.
28. **Collins S., Arulkumaran S., Hayes K., Jackson S. &Impey L. (**2013): "Oxford Handbook of Obstetrics and Gynaecology (flexicover)". Oxford University Press. Oxford, United Kingdom. 3rd edition.1-816.
29. **Buss C., Davis E., Class Q., Gierczak M., Pattillo C., Glynn L. & Sandman C.** (2009): "Maturation of the human fetal startle response: evidence for sex-specific maturation of the human fetus. Early Hum Dev 85: 633-638.
30. **Salihagic - Kadic A., Medic M., Kurjak** (2005): "4D sonography in the assessment of fetal functional neurodevelopment and behaviouralpaterns". Ultrasound Rev. Obstet. Gynecol. 5:115.
31. **Hayat T., Nihat A., Martinez-Biarge M., McGuinness A., Allsop J., Hajnal J. & Rutherford M.** (2011): "Optimization and Initial experience of a multi section balanced steady-state free precession cine sequence for the assessment of fetal behavior in utero. AJNR Am. J. Neuroradiol 32: 331-338.
32. **Natale R., Nasello-Paterson C. &Turliuk**R. (1985): "Longitudinal measurements of fetal breathing, body movements, heart rate, and heart rate accelerations and decelerations at 24 to 32 weeks of gestation". Am. J. Obstet. Gynecol. 151: 256-263.
33. **Ten Hof J., Nijhuis I. J., Mulder E., Nijhuis J., Narayan H., Taylor D., Westers P. &Visser G.** (2002): "Longitudinal study of fetal body movements: nomograms, intrafetal consistency, and relationship with episodes of heart rate patterns a and b". Pediatr. Res .52: 568-575.
34. **Moh W, Graham JM, Wadhawan I, and Sanchez-Lara PA** (2012): "Extrinsic factors influencing fetal deformations and intrauterine growth restriction". Jpregnancy**2012**:750485.

الملخص العربى

وصفميكانيكيلنمط حركة الطرف السفلى للأجنة اثناء المراحل الثلاثةللحمل

اهمية البحث: نعرف القليل من المعلومات عن حركة الجنين داخل الرحم اثناء الحمل، على الرغم من ان هذه المعلومات مصيرية لمعرفة النمو الطبيعى للجهاز العضلى الحركى. **هدف البحث:** يهدف البحث لوصف حركات الطرف السفلى للجنين، وصفا حركيا مجردا. **العينة:** خمسة و اربعون جنين تم تقييمهم من طبيب امراض نساء ، ثم قسمت العينة الى ثلاثة مجموعات متساوية (ا، ب، ج) على اساس مراحل الحمل الثلاثة (الاول ، التانى ، الثالث) بنفس الترتيب فيما بينهم **وسائل البحث:** تم تصوير الأجنة باستعمال سونار رباعى الأبعاد ، ثم تم تحليل حركة مفصل الفخذ، و مفصل الركبة، و مفصل الكاحل على ان تكون الحركة التى يتم قياسها مقسمة الى حركة زاوية لحظية، و مدى حركة كل مفصل، و سرعة حركة المفصل اثناء كل مرحلة من مراحل الحمل. **نتائج البحث:** اظهرت الدراسة ان هناك دلائل احصائية فى التغيرات بين حركة الركبة و الكاحل مما يدل على تطور نموها الحركى ، كما تأكدت هذه النتيجة نظرا للثبات النسبى لحركة مفصل الفخذ.