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The Role of 4D Ultrasound in the Assessment of Fetal Behaviour

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ABSTRACT

Fetal behavior is defined as any fetal action seen by the mother or fetus diagnosed by objective methods such as cardiotocography (CTG) or ultrasound. Analysis of the dynamics of the fetal behavior with morphological studies has lead to the conclusion that fetal behavior patterns are directly reflecting development and maturation of the central nervous system. The assessment of fetal behavior by 4D ultrasound could allow distinction between normal and abnormal fetal behavior patterns which might make possible the early recognition of fetal brain impairment.

Aim: *Assessment of fetal movements throughout the pregnancy using 4D ultrasound.*

Material and Method: *The study group included 144 healthy pregnant women with single pregnancies between 7-38 weeks of gestation. For the first trimester of pregnancy we assessed eight types of fetal movements and for the second and third trimesters 14 types of fetal movements and facial expressions. The analyzed parameters for each trimester of pregnancy can be used for performing antenatal neurodevelopment test, used the first time by Professor Kurjak.*

Results: *After 15-20 minutes 4D ultrasound examination, we found a pattern of fetal behavior for each trimester of pregnancy.*

Conclusions: *Dynamic evaluation of fetal behavior reflects directly the processes of maturation and development of the central nervous system. This can make the difference between normal and abnormal brain development and may be used for early diagnosis of neurological disorders that become manifest in perinatal and postnatal periods.*

Keywords: fetal behavior, 4D ultrasound, fetal movements

INTRODUCTION

In the past, registration of fetal movements and fetal heart rate auscultation were the only methods of the follow-up of fetal well being. In the last few decades, the development of new ultrasound techniques has allowed direct visualization of the fetus *in utero* (1,2).

4D ultrasound has recently been introduced in medical practice and complements 2D and 3D examination by obtaining images in real time. 4D ultrasound allows visualization of embryonic movements two weeks earlier than 2D ultrasound (1). In comparison with 2D ultrasound, 4D ultrasound offers real benefits for fetus's assessment prenatal condition. The most benefits of 4D ultrasound could be real time

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assessment of fetal face, grimacing, breathing movements, swallowing, mouthing, isolated eye-blinking and reveals the direction of the limbs. In a relatively short period of time 4D ultrasound stimulated multicentric studies on fetal and even embryonic behaviour with more convincing imaging than conventional 2D ultrasound. A large spectrum of neurological problems, such as attention deficit hyperactivity disorder, schizophrenia, epilepsy, autism could be result at list in part from prenatal neurodevelopment problems (1,2).

The fetuses with abnormal fetal behaviour should be followed at least till the age of two years when their categorization to disabling or non-disabling cerebral palsy can be possible.

It is well known that fetal movement occurs far earlier than a mother can register it, at the end of the embryonic period (1). Pattern of the movements, its quantity and quality is expanding rapidly during pregnancy, from gross movements of the whole embryo to organized movements and facial expressions towards the end of the pregnancy.

Understanding the relationship between fetal behavior and brain developmental processes in different periods of gestation makes it possible to distinguish between normal and abnormal central nervous system (CNS) development and early diagnosis of various structural and functional abnormalities. ❑

MATERIAL AND METHOD

The study is a prospective longitudinal study conducted in the Department of Obstetrics and Gynecology Hospital Elias for a three years period (January 2008 - December 2010). The study involved the follow-up of the fetal behavior throughout the pregnancy for normal fetuses derived from single pregnancies. We assessed qualitatively and quantitatively 8 types of movements during the first trimester and 14 types of fetal movements and facial expressions during the second trimester for 15-20 minutes. At the end of the examination we noticed a fetal behavior according to the gestational age.

Inclusion criteria:

The study included 144 healthy pregnant women with single pregnancies between 7-38 weeks of gestation.

The fetuses and mothers were considered "normal" after the 2D examination.

Exclusion criteria:

We excluded from the study the pregnancies with high maternal or fetal risk (hypertension, gestational diabetes, intrauterine growth restriction (IUGR), threatened preterm delivery, polyhydramnios, chromosomal abnormalities).

Movements analyzed in embryos and fetuses during the first trimester of pregnancy:

1) General movements –there are gross movements which consists of flexions and extensions of the trunk accompanied by passive limb movements. They appear in irregular sequences and were called vermicular movements (3,4);
2) Startles - fast movements that start in the limbs and spread to the neck and trunk (2,3);
3) Stretching - consisting of back extension, external rotation retroflex head and limbs (5);
4) Isolated upper limb movements - movements include flexion, extension, internal rotation, adduction, abduction without involving other parts of the body (5,6);
5) Isolated leg movements;
6) Head retroflexion movements;
7) Head anteflexion movements;
8) Head rotation movements.

Movements and facial expressions analyzed in fetuses during second and third trimesters of pregnancy:

1) Isolated eye blinking;
2) Mouthing (closed/open mouth);
3) Yawning – wide opening of the jaw is often accompanied by retroflex ion of the head and elevation of the arms (3). The retraction of the tongue is characteristic during intrauterine period (5,7);
4) Tongue expulsion;
5) Grimacing (smiling, frowning). They are important for facial paralysis diagnosis (objectified by the presence of asymmetry accompanied by limitation of movement from one face side) (2);
6) Swallowing and sucking - swallowing is revealed by mouth opening followed by tongue movement and/or larynx. Sucking is visible very clearly in the second half of the pregnancy (the fetus is sucking thumb or umbilical cord) (2,3);
7) Complex movements - hand to head movements –in this pattern of movements the hand touches the face and the fingers are flexed or extensed. These movements occur at the end of the first trimester and initially

they are only accidental contacts (8,9). They can be divided into several subgroups:

- Hand to head - hand touches parieto-occipito-temporal region (5),
- Hand to mouth - hand or fingers touch the mouth, lips (4,5),
- Hand to face - hand touches the cheeks, forehead, chin,
- Hand to eye - hand or fingers touch the eye region,
- Hand to ear - hand touches the ear
  - Head retroflexion
  - Head anteflexion
  - Head rotation.

The movements are normal if they are complex, involving head, trunk and limbs, smooth and increase or decrease in amplitude. They should last at least 20 seconds (10).

The movements are considered abnormal if they are monotonous, repetitive, chaotic with lack of complexity and with muscle contracture (4,7). ❑

RESULTS

Statistical analysis of the incidence of normal movements in the first trimester of pregnancy showed significant changes in general movements, stretching, isolated arm and leg movements, head retroflexion, head anteflexion and head rotation.

Throughout the first trimester we noticed increased incidence of fetal movements with increasing gestational age (Fig. 1, 3, 4, 5, 6, 7, 8). Only in the startle movements their number seems to occur stagnantly during the 7-14 weeks. In this case we noticed a significant correlation with gestational age, objectified by a large dispersion of points along the regression line (Fig. 2).

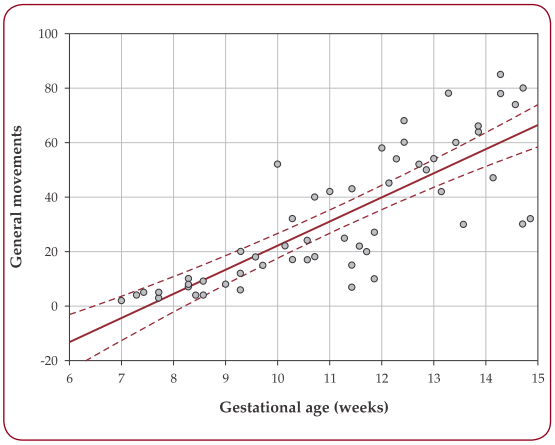

FIGURE 1. Linear regression of the frequency of general movements in the first trimester(y = -65.963 + 8.820x, r^2 = 0.651, p <0.001)

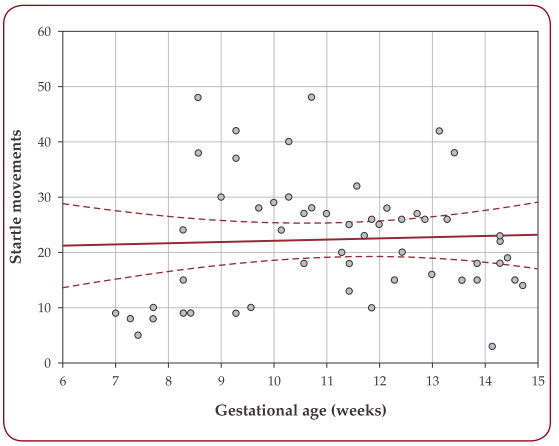

FIGURE 2. Linear regression of the frequency of startle movements in the first trimester (y = 19.959 + 0.213x, r^2 = 0.491, p <0.454)

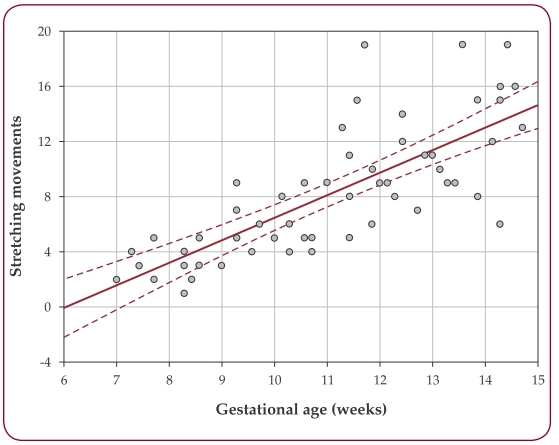

FIGURE 3. Linear regression of the frequency of stretching movements in the first trimester (y = -9.916 + 1.639 x, r^2 = 0.586, p <0.001)

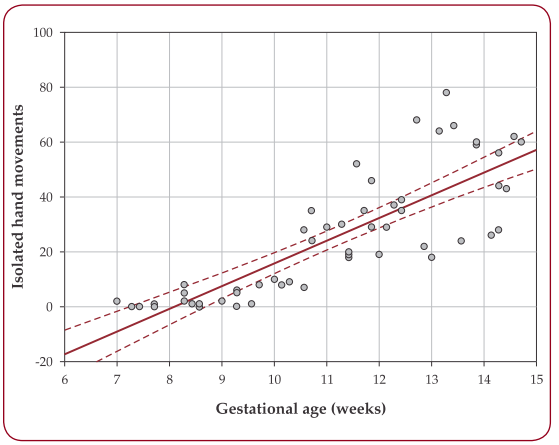

FIGURE 4. Linear regression of the frequency of isolated hand movements in the first trimester (y = -66.911 + 8.276x, r^2 = 0.678, p <0.001)

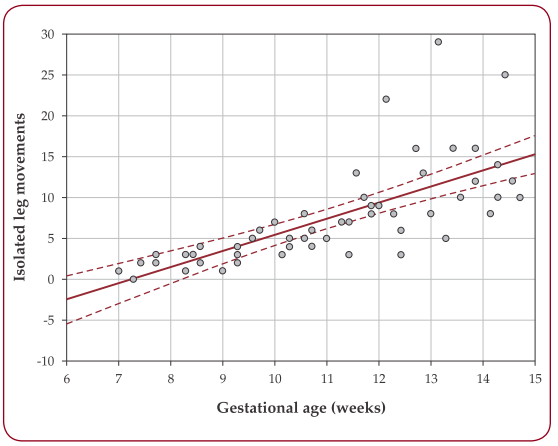

FIGURE 5. Linear regression of the frequency of isolated leg movements in the first trimester (y = -14.342 + 1.974x, r^2 = 0.518, p <0.001)

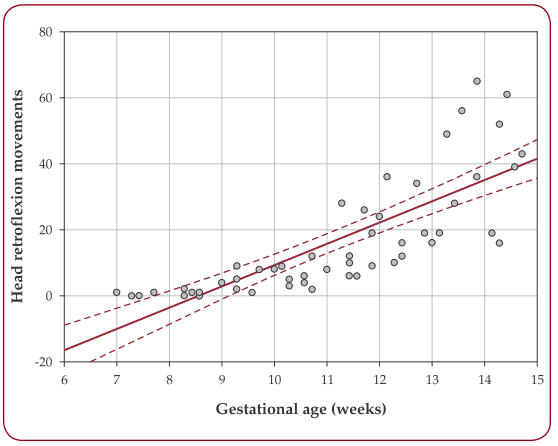

FIGURE 6. Linear regression of the frequency of head retroflexion movements in the first trimester (y = -55.098 + 6.440x, r^2 = 0.638, p <0.001)

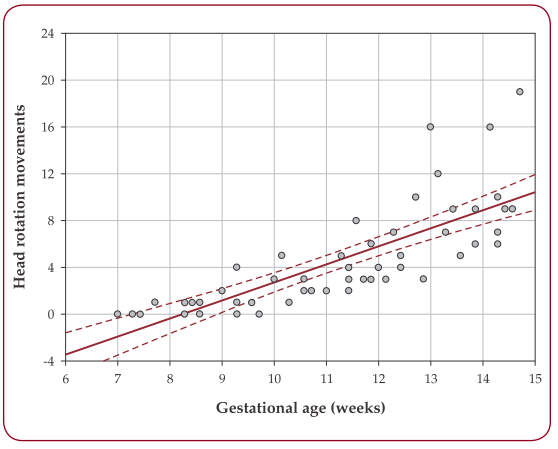

FIGURE 7. Linear regression of the frequency of head rotation movements in the first trimester (y = -12.702 + 1.541x, r^2 = 0.609, p <0.001)

During the second half of the pregnancy the motor behavior significantly increases in frequency and variability. The force of the movements increases and changes fetal position. The hands touch uterine wall and different parts of the body or the umbilical cord.

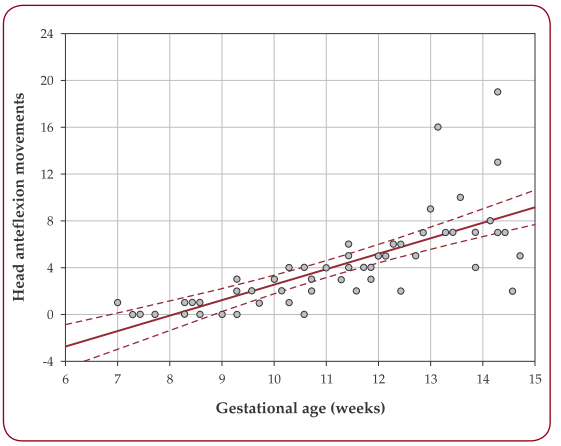

FIGURE 8. Linear regression of the frequency of head anteflexion movements in the first trimester (y = -10.647 + 1.321x, r^2 = 0.545, p <0.001)

After statistical analysis of movements in the second and third trimesters we have achieved linear and polynomial regressions of the incidence of fetal movements and facial expressions. At the beginning of the second trimester the number of all types of movements obviously increases.

We have represented facial expressions by polynomial regressions and noticed fluctuations and variances. All types of facial expressions have a peak frequency in the second trimester (Fig. 10, 11, 12, 13, 14), except in the eyelid movements which start to increase after 23th week (Fig. 9). Towards the end of the pregnancy, the fetus displays a stagnant or a slight decrease of facial expressions.

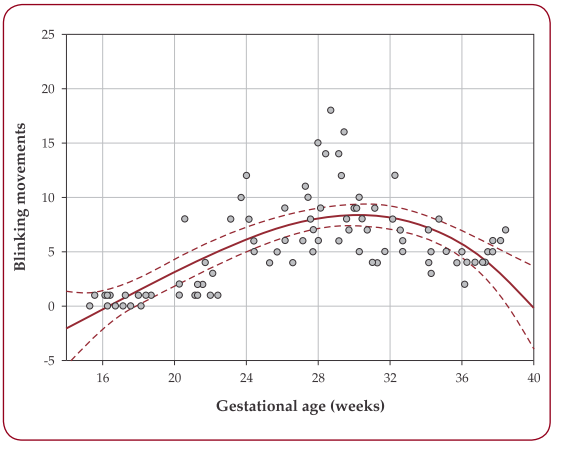

FIGURE 9. Polynomial regression of the frequency of blinking movements in trimesters II-III (y = -3.609 - 0.933x + 0.101x^2 - 0.00189x^3, r^2 = 0.495, p <0.001)

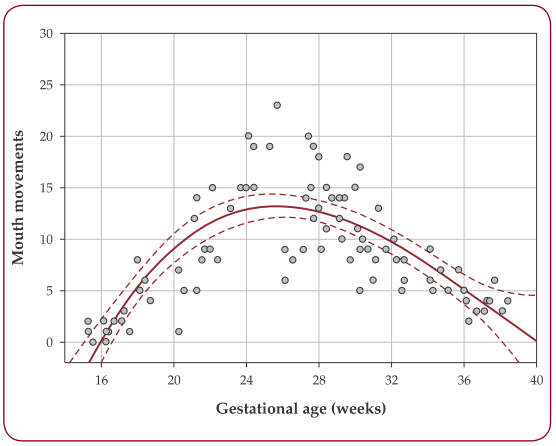

FIGURE 10. Polynomial regression of the frequency of mouth movements in trimesters II-III (y = -111.189 + 11.706x - 0.346x^2 + 0.00308x^3, r^2 = 0.614, p <0.001)

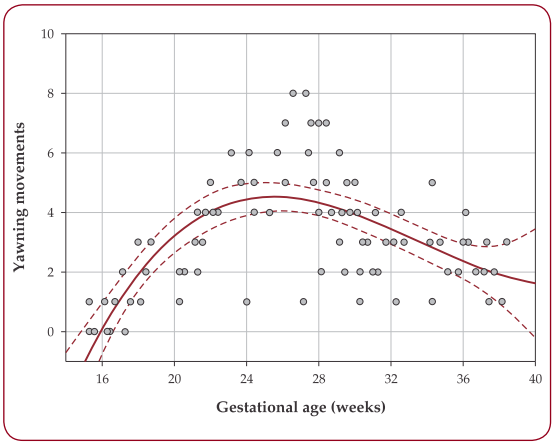

FIGURE 11. Polynomial regression of the frequency of yawning movements in trimesters II-III (y = -42.577 + 4.645x - 0.147x^2 + 0.00146x^3, r^2 = 0.471, p <0.001)

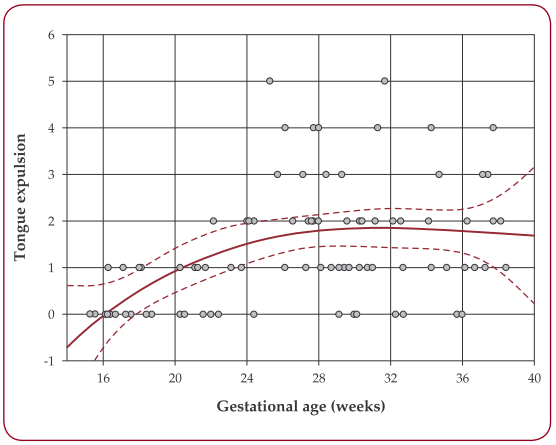

FIGURE 12. Polynomial regression of the tongue expulsion in trimesters II-III (y = -9.693 + 0.965x - 0.0264x^2 + 0.000234x^3, r^2 = 0.227, p = 0.005)

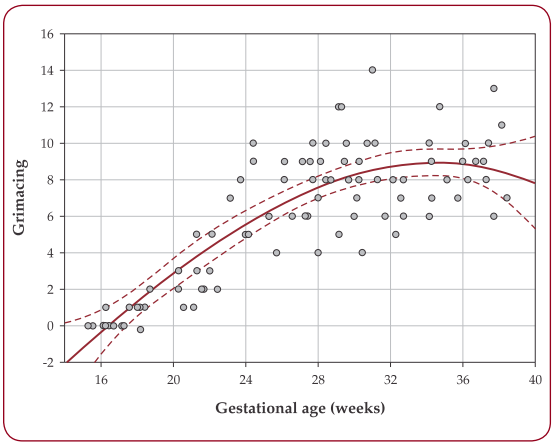

FIGURE 13. Polynomial regression of the grimacing in trimesters II-III (y = -14.939 + 0.855x + 0.0106x^2 - 0.000442x^3, r^2 = 0.716, p <0.001)

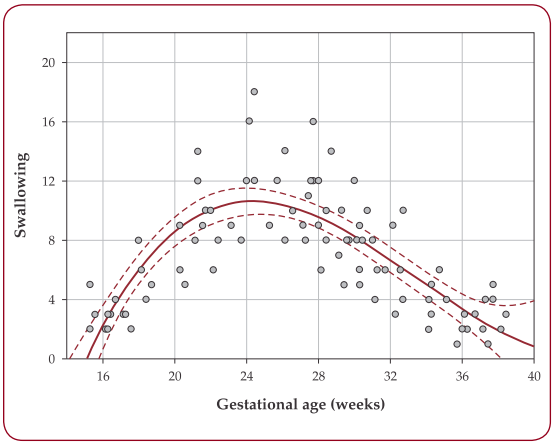

FIGURE 14. Polynomial regression of the frequency of swallowing in trimesters II-III (y = -93.720 + 10.586x - 0.342x^2 + 0.00340x^3, r^2 = 0.617, p <0.001)

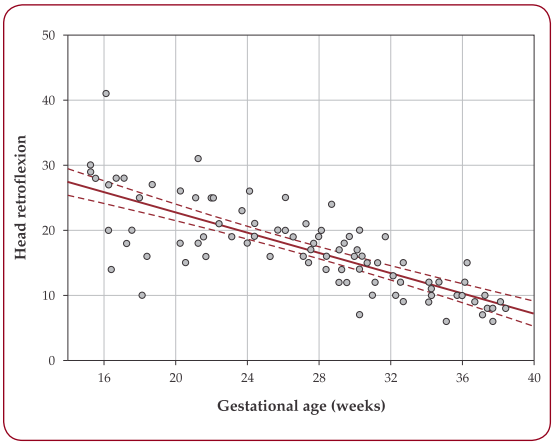

FIGURE 15. Linear regression of the frequency of head retroflexion in trimesters II-III (y = 38,307 - 0.777x, r^2 = 0.594, p <0.001)

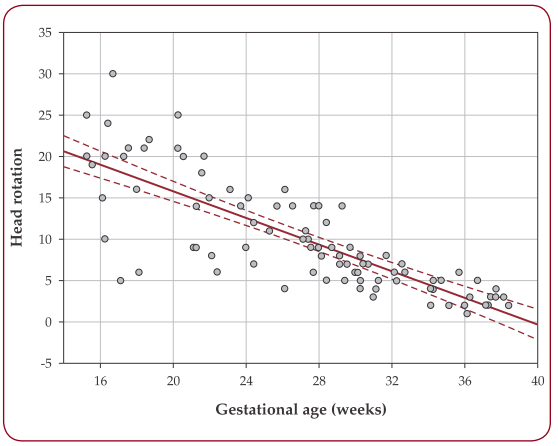

FIGURE 16. Linear regression of the frequency of head rotation in trimesters II-III (y = 31.895 - 0.804x, r^2 = 0.646, p <0.001)

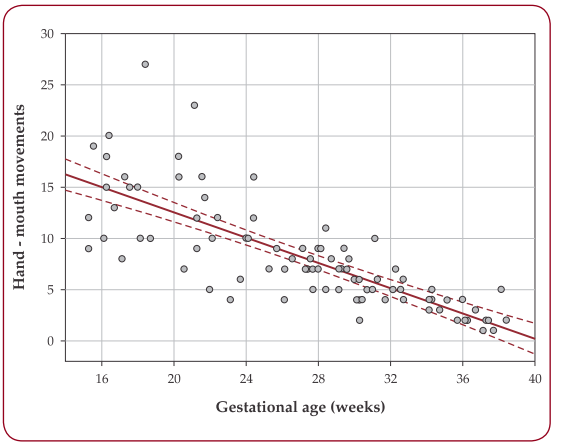

FIGURE 19. Linear regression of the frequency of hand - mouth movements in trimesters II-III (y = 24,879 - 0.617x, r^2 = 0.615, p <0.001)

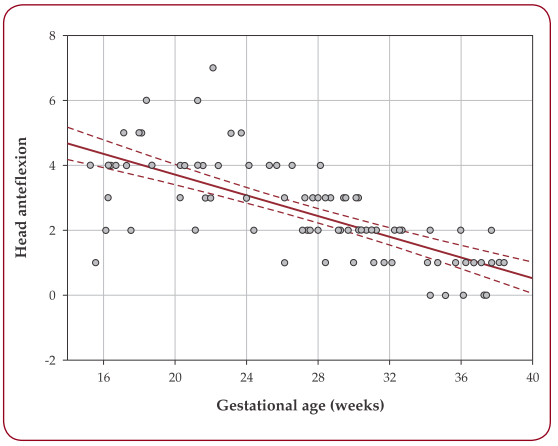

FIGURE 17. Linear regression of the frequency of head anteflexion in trimesters II-III (y = 6.906 - 0.159x, r^2 = 0.506, p <0.001)

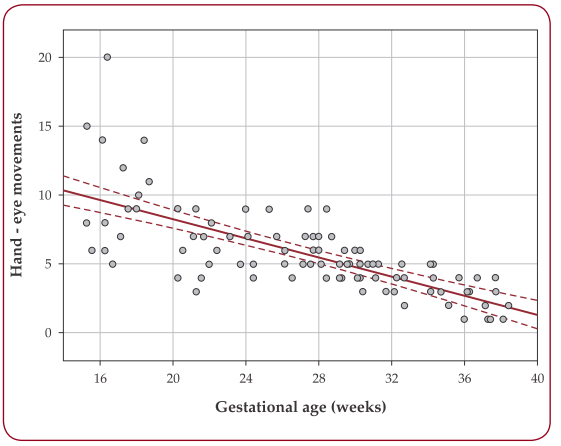

FIGURE 20. Linear regression of the frequency of hand - eye movements in trimesters II-III (y = 15.220 - 0.346x, r^2 = 0.517, p <0.001)

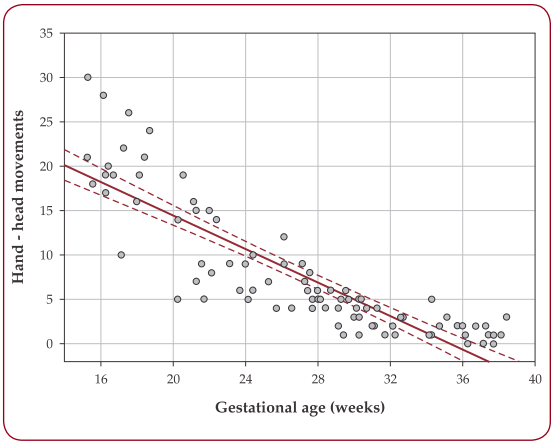

FIGURE 18. Linear regression of the frequency of hand - head movements in trimesters II-III (y = 33.396 - 0.944x, r^2 = 0.746, p <0.001)

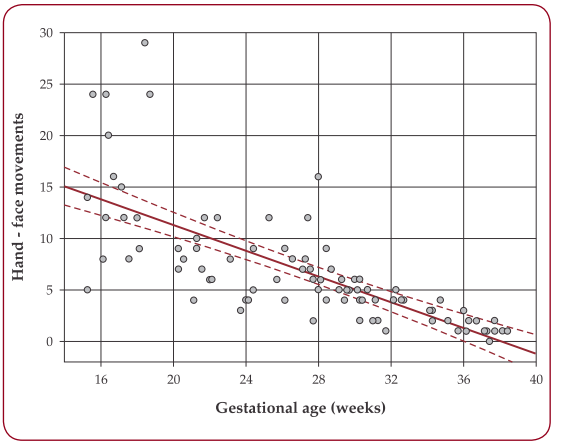

FIGURE 21. Linear regression of the frequency of hand - face movements in trimesters II-III (y = 23.856 - 0.625x, r^2 = 0.536, p <0.001)

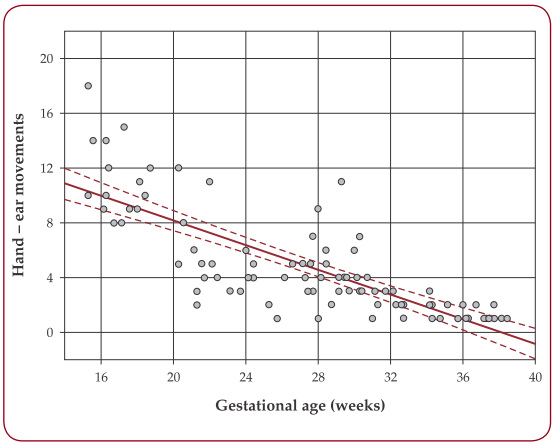

FIGURE 22. Linear regression of the frequency of hand – ear movements in trimesters II-III ($y = 17.132 - 0.449x$, $r^2 = 0.605$, $p < 0.001$)

All types of movements hand-head (Fig.18, 19, 20, 21, 22) and head anteflexion movements, head retroflexion movements and head rotation (Fig. 15, 16, 17) show a decrease in frequency between the beginning of the second trimester and the end of the third trimester. ❑

DISCUSSION

In the first trimester, fetal movements grow rapidly in frequency and complexity. If around 7 weeks of pregnancy only gross movements are visible, at the end of the first trimester fetus presents complex movements of the head, limbs and fingers. Initially hand contact with different parts of the body or the uterine wall is accidental (2).

In the second half of the pregnancy, the motor behavior significantly increases in frequency and variability. After 15 weeks of pregnancy, 15 types of movements are finalized (3): general body movements, isolated arm movements, isolated leg movements, head retoflexion, anteflexion and rotation, hand to head, hand to eye, hand to mouth, hand to face, hand to ear, mouth movements: yawning, sucking, swallowing, opening/closing the mouth. Mouth movements could be observed, particularly, during the absence of general movements periods and they reflect normal neurological development of the fetus (1,2,5).

Additionally, during the second trimester, facial expressions and eye movements occur. The first eye movements are sporadic and occur at about 18 weeks. Around 24-26 weeks, eye movements are more frequent and systematic alternating with periods when they are absent.

All types of facial expressions (movements of the mouth, smiling, frowning) showed a maximum frequency at the end of the second trimester (11).

In late pregnancy, fetal movements show a decline and the periods of rest start to grow. This decrease is rather a consequence of the brain maturation processes than the reduced amount of amniotic fluid (2,3).

The results of multicentric studies from Croatia, Spain, Turkey, Qatar, Sudan and Japan, showed similar distribution of fetal movements according to gestational age.

The study of fetal behaviour was a concern (even before the appearance of 4D ultrasound) for teams coordinated by De Vries and Prechtl. Five years ago, Professor Kurjak implemented antenatal neurodevelopment test (KANET) in Zagreb University hospital. The score is calculated after the assessment quantitatively and qualitatively of the parameters described above. Further, the assessment of the fetal behaviour was applied in other university centers from Croatia, Spain, Turkey, Qatar and Japan. In cases of definitely abnormal or borderline score the test should be repeated every two weeks till delivery. After that the babies require postnatal neurological development follow-up for a two years period. ❑

CONCLUSIONS

Behaviour is closely related to fetal development and maturation processes of the central nervous system. Widespread assessment of the fetal movements can diagnose early many neurological diseases that have their origins more in peri- and postnatal periods than during intrauterine period.

The identification of neurological problems during fetal life is based on evaluation of opening of the eyes, variety of facial expression, primary reflexes (rhythmical burst in the sucking pattern) and quality of general movements. The identification of dynamic and static patterns of the symptoms may be helpful to date precisely the time when the insult occurs.

The major problem in studying fetal behavior is that it requires a significant amount of time and it has not become an ultrasound exam routine. The bias in examination can be eliminated by use of ultrasound recordings.

Frequent use of the KANET score would bring a series of benefits and would solve situations in which obstetriciens are considered accountable for neurological injury in the neonatal period.

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