The quality of fetal arm movements as indicators of fetal stress

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ABSTRACT

Background: Although a number of studies have found that maternal stress affects the fetus, it is unclear whether jerky fetal movements observed on ultrasound scans are indicative of fetal stress, or whether they are part of normal development.

Aims: The present study was designed to examine the relationship between jerky fetal arm movements in relation to fetal age and stress.

Methods: Video recordings were made of routine ultrasound scans of 57 fetuses (age range 8 to 33 weeks) classified into three age groups: 1st trimester (8–12 weeks, N = 9), 2nd trimester (13–24 weeks, N = 38), and 3rd trimester (26–33 weeks, N = 10). Following previous research on stress behaviour in neonates, a fetal index of stress was derived from frequency of hiccup, back arch and rhythmical mouthing.

Results: Results indicated that while stress level was unrelated to fetal age, jerkiness of arm movements was significantly associated with the fetal stress index but not age.

Conclusions: Our findings suggest that jerky arm movements in fetuses are suggestive of fetal stress.

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1. Introduction

In healthy pregnancies, fetal movements have been documented to be discernible by ultrasound at 8–9 weeks gestation and include general movements, startle, hiccup, stretch, isolated arm and leg movements, hand-to-face contact, jaw opening, anteflexion, retroflexion and rotation of the head, with stretches and hand-to-face contacts evident from around 10 weeks whereas eye-movements have been documented from around 14 weeks of age [1–4]. Most movements in healthy fetuses are “performed strikingly similarly and fluently throughout prenatal life” with the exception of startles, hiccups, isolated twitches and head retroflexion [4:704]. These fluent or smooth fetal movements are not only indicative of healthy development prenatally but also are positively correlated with postnatal self-regulation scores on the Neonatal Intensive Care Unit Network Neurobehavioral Scale [NNNS, 5]. Although some authors report non-linear quantitative changes in movements, others suggest that there is continuity from prenatal to postnatal life. For example, deVries and Hopkins [4] reviewing various movement patterns, propose that general movements increase from 8 to 28 weeks, and then decline from 28 to 36 weeks. Other researchers suggest that there is continuity in movement patterns before and after birth [4,6] and argue for a continuum of distinct motor patterns from 8 weeks postmenstrual age to around three months of age in the postnatal period [6].
the Spielberg State-trait-Anxiety Inventory when the fetus was of 36 weeks gestational age. The main finding was that the percentage duration of fetal movements did not differ between women with low and high state and trait anxiety scores. Thus the issue raised is whether there is a way to evaluate fetal stress based on fetal rather than maternal stress. In the light of research indicating a prenatal to postnatal continuum in quality of movements, it is suggested that the definition of stress movements can be derived from movements of the neonate under stress. Such movement classification has been derived from the NNNS (NICU Network Neurobehavorial Scale) which provides a comprehensive assessment of neurological and behavioural functioning of newborns exposed to high-risk conditions such as drugs and prematurity [16]. Neonates exposed to high-risk conditions are more stressed. Their stress is expressed in more movements of the face (e.g. rhythmical mouthing) and trunk (e.g. hiccup and back arch) compared with neonates not exposed to high risk. Hence Lester and Tironick [16] suggest that rhythmical mouthing, hiccup and back arch are movements indicative of stress.

Assuming that the quality of fetal movements provides a means of assessing fetal well-being, the present study, in contrast to others which assessed potential stress indirectly through maternal report, examines stress in the fetus by directly observing various movements which have been shown to be indicative of stress in the neonate (e.g. hiccup, back arch and rhythmical mouthing) and applying it to the fetus. In sum, to date, although a number of studies have examined fetal stress in relation to stress reported by the mother and other stressors such as growth restriction, maternal diabetes and smoking or alcohol consumption during pregnancy, it is not clear whether the quality of fetal limb movements in terms of being jerky is related to fetal stress level or is a normal age-related phenomenon in the human fetus. In other words, are jerky limb movements predicted by age or stress or both?

Given that jerky movements or “body twitches” indicate stress rather than pain in premature infants at 32 weeks gestational age [17], the present study was designed to test the prediction that the relative duration of jerky arm movements, irrespective of fetal age, are related to whether stress was present or not. We derived a stress index, based on findings in stressed neonates [16] which is composed of one fetal facial movement (rhythmical mouth movements) and two fetal trunk movements (hiccup and back arch). We hypothesized that fetuses not exhibiting stress according to our measure will show relatively fewer jerky arm movements irrespective of age, compared to fetuses with rhythmical mouthing and hiccups and back arching who will display more jerky arm movements.

2. Method

2.1. Participants

Anonymous video recordings were made of routine ultrasound scans of 57 healthy fetuses, with gestational ages ranging from 8 to 33 weeks. 2-D scans were made using Toshiba Aplio XV ultrasound using a 3.5-MHz transducer. The scans were directly recorded using a VCR interface to a Panasonic video cassette recorder AG 5700 for off-line analysis. The study was approved by the Grampian Ethics Board and all participants gave their informed consent. Gestational age was based on rump-to-crown length measurements for fetuses from 8 to 13 weeks, and a mean of measurements of biparietal diameter, femur length and abdominal circumference for fetuses between 17 and 40 weeks. All fetuses were scanned and videotaped when they showed some activity. In rare cases when fetuses showed no activity, mothers were asked to walk around and come back after 15 min. Fifty-seven fetuses were classified into three age categories: 1st trimester (8–12 weeks, n = 9), 2nd trimester (13–24 weeks, n = 38), and 3rd trimester (26–33 weeks, n = 10).

2.2. Data extraction

In accordance with others [15,18,19], we analysed the duration of fetal movements. The length of the videoclips depended on the duration of a routine scan, and thus varied among fetuses. First trimester scans typically lasted around 5–10 min whereas those carried out in the second and third trimesters were about 10–15 min. For the youngest group, video clips which could be coded, in that the picture was clearly visible with no obstructions, lasted a mean of 4.18 min (range: 3.05–6.15); for the middle group a mean of 11.97 min (range 2.43–20.60) and for the oldest group 8.98 min (range 1.07–23.15). Because of this variation, we calculated the duration per minute relative to the length of observed behaviours for the fetal face, head, trunk and upper limbs.

The videotapes were digitized and the following behaviours were coded separately frame-by-frame using the OBSERVER registration system [20]: hiccups, back arch, rhythmical mouthing, head movements, and arm movements (jerky, smooth, and no movement). Portions of the videoclip where the ultrasound probe was moving or where the image was fuzzy and hence not codeable were excluded from the analysis.

Based on this coding scheme, we identified the occurrence of hiccups, back arch, and rhythmical mouth movements, and calculated a stress index as the sum of the mean relative percentage duration of these three behaviours. The amount of stress in terms of relative duration of stress movements observed was derived from the relative percentage of duration of coded time that the fetus showed hiccups, back arching, and rhythmical mouth movements. On the basis of the relative durations, two stress levels were identified: no stress (19 fetuses showing no instances of hiccups, back arching, and rhythmical mouth movements), and stress (38 fetuses).

2.3. Reliability

Reliability of coding for each of the behaviours observed was established between two coders for nine fetal records. The mean Cohen’s Kappa was .83, with a range of .71–.92. Five additional fetal records were coded by a third coder for “probe movement/image cannot be coded” which resulted in a mean Cohen’s Kappa of .90 (range .89–.93). On the same five fetal records the third coder coded each of the behaviours observed resulting in a mean Cohen’s Kappa when compared to the first coder of .92, (range .90–.94).

3. Results

3.1. Fetal movements in relation to fetal age and length of observational period

As the relative durations of fetal movements were in general not normally distributed, the Kruskal–Wallis test [21], was used to determine whether fetal age measured by trimester was related to the relative duration of behaviours coded. Most of the behaviours shown were not related to the age of the fetus (smooth arm movements: K = 1.316, p = .510; jerky arm movements: K = 4.753, p = .093; arms still: K = 5.183, p = .075; isolated jaw movements: K = 271, p = .873; head movements involving rotation: K = 2.960, p = .228; still head: K = 454.7, p = .103; still face: K = 2.826, p = .243, each with 2 df). However anteflexion of the head (head bending forward), showed a relationship: K = 7.899, p = .019, with the middle trimester demonstrating the longest relative duration. Thus, for most movement types, there is no significant relationship with fetal age: but for one specific movement type, the relationship is increasing, then decreasing.

The relationship between the relative duration of jerky arm movement and length of coded observational period was examined.
using the Spearman rank correlation. There was no evidence of any statistical relationship between the two \((r = 0.013, p = 0.930)\).

3.2. Fetal age in relation to the stress index derived from a combination of rhythmic mouthing, hiccupping and backward arching

Fetal age was not related to stress level as derived from the stress index \((K = 2.27, p = 0.893)\).

3.3. Jerky arm movements in relation to stress level and fetal age

We examined the relative duration of jerky arm movement according to stress group (no stress versus some stress) and age. For seven of the fetal ultrasound scans, arms were not visible for the entire period of observation, and these fetuses were removed from the analysis.

To investigate the relative importance of stress and trimester age on the relative duration of jerky arm movements, we used two approaches. Firstly we analysed the measure as continuous, using both a standard two-way analysis of variance and a non-parametric rank-based equivalent to the two-way analysis of variance [22]. Secondly, we categorised the measure into no jerky movement, low duration (up to 15%) and moderate duration (15% or more), choosing the cutpoint of 15% pragmatically as that which divided the sample into approximately equal sized groups. We then used multinomial logistic regression [23; 267] to examine the effect of age and stress.

The parametric and non-parametric forms of the two-way analysis of variance of the relative duration of jerky movements gave similar results in terms of significance. Fetal age showed no significant effect (parametric \(F = 1.475, \text{df} = 2.46; p = 0.239\); non-parametric \(F = 2.666, \text{df} = 2.46; p = 0.080\)) whereas stress was significant in both tests (parametric \(F = 4.243, \text{df} = 1.46; p = 0.045\); non-parametric \(F = 4.322, \text{df} = 1.46; p = 0.043\)). The multinomial logistic regression analysis modelled the probabilities of belonging to each of the three jerky movement categories as a linear function of trimester age category and stress category, and then tested the relative significance of each potential predictor through a likelihood ratio test. This analysis similarly showed no significant association for trimester age (LRTS = 5.121 on 4 df, \(p = 0.275\)) but a strong association with stress (LRTS = 8.166 on 2 df, \(p = 0.017\)).

Table 1 shows in more detail the relationship between stress level and the relative duration of jerky arm movements. The proportion of fetuses exhibiting some stress is 55% in those exhibiting no jerky arm movement, rising to 64% for those showing some jerky movement, and 94% for those in the moderate jerky arm movement group. A chi-squared test of independence on this table was significant \((X^2 = 6.551 \text{on 2df}; p = 0.038)\).

4. Discussion

In the present study, we employed an index of fetal stress based on hiccupping, back arcing, rhythmic mouth movements and related it to the quality of fetal upper limb movements. The relative duration during which fetuses exhibited stress behaviours was related to the level of jerky arm movements in a sample of healthy fetuses covering the age range of 8 to 33 weeks. The results indicate that the observed relative duration of jerky arm movements by the fetus were significantly related to whether “stress” was present or not, measured by a stress index derived from the three stress movements of the fetal face and trunk. There was no evidence that the relative duration of jerky arm movements was related to the age of the fetus and thus the quality of arm movements is an indicator of the fetal stress level.

Continuity in movement patterns before and after birth is well established [3,4,6,24]. However, not only movement patterns, but also other aspects of development are continuous across the birth divide. According to the fetal programming hypothesis [25], the adverse events in the intra-uterine environment can affect long-term development, such that, for example, disturbed prenatal growth has a negative influence on the development of the cardiovascular system and favours the occurrence of hypertension, insulin resistance, and hypercholesterolemia, in adult life. Furthermore, Laplante, Barr, Brunet et al. [26] found that prenatal stress has an effect on language and intellectual functioning in toddlers. Moreover, some researchers have reported that prenatal maternal anxiety and stress were related to an increase in fetal heart rate as well as motility [27] whereas others [15] did not find any relation between maternal anxiety and durations of movements observed in the fetus and the neonate. Hence, this indirect measure of stress exposure might not identify the true stress a fetus might experience.

Given that some researchers have found that a decline in fetal movements indicates fetal stress [28,29], while others obtained a relation between stress and increase of fetal movements [30] the quality of the movements in terms of being jerky needs to be a focus of subsequent studies. If that is the case, it could be that coding isolated movements in terms of jerkiness might help identify whether a fetus is stressed or not. In the present study, all fetuses were scanned during mid-morning. In future, it would be beneficial to examine the same fetus at different ages and times of day.

In our sample, 72% of fetuses showed some stress movement. Should we be alarmed? We believe that there is no need to worry. Indeed animal models suggest that a degree of stress might be necessary for healthy development [31]. Research on rats suggests that mild prenatal stress enhances rather than hinders learning performance [31]. However, Di Pietro [32] warns that one needs to be careful when generalizing such results to humans, given that tests on effects of prenatal stress might be contaminated with what happened to the neonate after birth. Hence, more research is essential.

One potential weakness of our study is the lack of follow-up data. We were not able to assess the postnatal stress level of the fetuses which would have provided an additional clinical outcome measure. Another weakness is the lack of background data both on the mother and on the fetus. One of the conditions of using routine ultrasound scans was that the data was anonymised and hence the background data could not be assessed in the present study.

In conclusion, these findings demonstrate an association between the type of fetal mouth and trunk movements and the quality of upper limb movements in a sample of healthy fetuses covering the age range of 8 to 33 weeks. They add to a growing body of research examining fetal movements relative to stress. In contrast to other studies, we compared whether movements indicative of stress (e.g. rhythmic mouthing, hiccupping and back arching) are related to the quality of fetal limb movements. Potentially, jerky arm movements could be a proxy for fetal stress and could be identified in routine ultrasound scans.

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Conflict of interest

The authors declare that they have no conflicts of interest.

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