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Correlation between umbilical cord length and gross fetal movement as counted by a fetal movement acceleration measurement recorder

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ABSTRACT

Introduction: The fetal movement acceleration measurement (FMAM) recorder has made it possible to count gross fetal movements over many hours. Our purpose was to examine the relationship between umbilical cord length and fetal movements as counted by the FMAM recorder.
Methods: Sixty-two pregnant women recorded fetal movements weekly from 28 weeks to term. The ratio of 10-s periods in which movement occurred to total time was calculated as a movement index. Umbilical cord length was measured at delivery. (1) Multiple linear regression analyses were conducted with six explanatory variables (primipara / multipara, anterior / posterior located placenta, placental weight, the mean movement index of 28–31, 32–35, and 36–39 week) and a response valuable (umbilical cord length). (2) All women were divided into groups of shorter, middle, and longer cord length, specifically less than 50 cm, between 50 and 60 cm, and more than 60 cm. The movement index was compared among the three groups at 28–31, 32–35, and 36–39 weeks.
Results: A total of 2355.6 h from 368 night records were available. (1) There were no relationships between the cord length and the movement index of 28–31, 32–35, and 36–39 weeks (p = 0.090, 0.235, 0.129, respectively). (2) There were no differences in the movement index among the three groups at 28–31 and 32–35 gestational weeks (p = 0.096, and 0.465, respectively); however, the longer cord group had a greater movement index than the other two groups at 36–39 weeks (p = 0.0008).
Discussion: This study suggested that fetal movement near term is an important factor in determining whether cord length becomes relatively longer in normal pregnancies.

Introduction

The umbilical cord is an important lifeline for a fetus, and abnormalities of the umbilical cord sometimes cause fetal mortality or morbidity [1]. One of the abnormalities is its length. A short cord increases the probability of non-reassuring fetal status, emergent cesarean delivery, and neonatal asphyxia [1]. A long cord is associated with entanglement, knots, prolapse, and a thrombus of the cord. A long cord also increases the probability of neonatal asphyxia [2,3].

Though little is known about the factors determining umbilical cord length, fetal movement is considered by many to be one of the promoting factors. There have been several animal experiments suggesting just that. Moessinger et al. [4] reported that tensile forces on the cord, secondary to fetal movements, were an important determinant of cord length in rats. Baron S et al. exposed cocaine [5] and alcohol [6] to fetal rats to reduce fetal movement and demonstrated that these exposures made umbilical cords shorter. Similarly, Katz V et al. [7] exposed beta-blockers to fetal rabbits to reduce fetal movement and concluded that a decrease in fetal movement led to a shorter cord.

On the other hand, several clinical studies reported an indirect relationship between cord length and fetal movements in human beings. Miller et al. [8] reported that a short umbilical cord was found in newborns with gross structural or functional limb defects that would limit intrauterine movement. Kivistö J et al. [9] studied pregnant women taking selective serotonin reuptake inhibitors and found that new-borns exposed to the medicine had longer umbilical cords. They said that the increased cord length could be explained by the increase of fetal movement caused by the medicine. Wright D and Chan GM [10] studied the relationship between the bone mass of infants and their umbilical cord lengths. They found that infants with a short cord length had less bone strength and that the finding was likely due to decreased fetal movement.

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Therefore, fetal movement seems to promote cord length. On the other hand, a longer cord may give a baby more freedom to move. However, there have been no reports that demonstrate a direct correlation between fetal movement and cord length in human beings. That is because there has never been a practical way to count fetal movements in many fetuses over long periods of time.

We have developed a fetal movement acceleration measurement recorder (FMAM recorder, http://e-mother.co-site.jp) that was designed for home use [11,12]. The recorder records gross fetal movements by detecting oscillations of the mother's abdominal wall caused by fetal movements. In a previous study, we simultaneously observed gross fetal movements and maternal abdominal wall oscillations respectively by ultrasonography and the FMAM recorder to examine the agreements between the two. The agreements expressed by prevalence-adjusted bias-adjusted kappa were 0.82-0.83 which meant almost perfect values [11]. Furthermore, using the FMAM recorder, we recently made normal reference values for gross fetal movement counts and demonstrated that the values are similar to those made using ultrasonography [12]. The FMAM recorder has made it possible to count gross fetal movements over many hours.

The purpose of the current study was to examine the relationship between umbilical cord length and fetal movements as counted by the FMAM recorder.

Materials and methods

Counting fetal movements

The FMAM recorder was described in detail in our past studies [12,13]. It weighs 290 g and can be used at home. It has two acceleration sensors: one is a fetal movement sensor (FM sensor), which attaches to the mother's abdomen, and the other is a mother's movement sensor (MM sensor), which attaches to her thigh. The sensitivity of the FM and MM sensors is 700 mV/0.1 G and 120 mV/0.1 G, respectively. The FM sensor detects oscillations of the mother's abdominal wall caused by gross fetal movements. The recorder is unsuitable when the mother moves frequently because the mother's body movements themselves also cause oscillations. That is why the recorder is used during her sleep. However, the mother does move occasionally even when she is asleep. In principle, when the MM sensor detects no maternal leg movement and the FM sensor detects oscillations of her abdominal wall, gross fetal movements are judged to have occurred.

The mothers were asked to record fetal movements during their sleep weekly or biweekly after 28 weeks, because the accuracy of the FMAM recorder is limited before 28 weeks [11]. The data were uploaded to a PC. We accepted records only when data could be obtained for more than 4 h per night. The recording was divided into 10-s time intervals (epochs), meaning 360 epochs per hour. All epochs were reviewed to determine whether any fetal movements occurred within each epoch. An epoch with any fetal movements was judged to be one positive epoch. The decision was made using a custom-made software system (Version 1.04 A, NoruPro Light Systems, Inc. Tokyo Japan), which was developed for the FMAM recorder [12,14]. The ratio of positive epochs to all epochs during one night was calculated as the movement index.

Subjects

There were a total of 62 pregnant women who could record fetal movement for more than 4 h per night and delivered a baby at term between February 2010 and the end of 2016 at Teikyo University Hospital. None of the mothers had any medical complications, and none of the babies had any anomalies or neurological problems. The characteristics of the mothers and babies are shown in Table 1.

Methods

After all delivery, the length of the umbilical cord was measured after separated from the baby. The cord segment attached to the baby was left routinely 3 cm in length. A trained midwife checked cord abnormalities and measured cord length using a ruler. The length was determined as the nearest centimeters and added 3 cm in order to get the total length.

First, the correlation between the cord length and the movement index was examined. In a previous study, we reported that the movement index decreases as pregnancy progresses, with the decrease being relatively rapid around 32–35 weeks [12]. Therefore, the recordings were divided into three groups based on gestational weeks, i.e. 28–31, 32–35, and 36–39 weeks, and a mean value of the movement index was calculated for each period per one woman. Multiple linear regression analyses were then conducted with six explanatory variables (primipara / multipara, anterior / posterior located placenta, placental weight, and the mean movement index value of 28–31, 32–35, and 36–39 week) and a response valuable (umbilical cord length).

Next, all women were divided into three groups depending on the cord length. The average umbilical cord length has been reported to be around 55 cm [2]; therefore, when the cord length was 50–60 cm, the women were classified in the middle cord group. The shorter or longer cord length groups were less than

Table 1
Characteristics of all women and three groups depending on the cord length.

	total	groups			
		short	middle	long	p
n	62	20	22	20	
mother's age	32.9 (20.0, 44.0)	32.5 (20.0, 44.0)	33.4 (25.0, 41.0)	32.8 (24.0, 41.0)	0.798
BMI	21.1 (16.8, 28.0)	21.4 (17.6, 28.0)	20.4 (16.8, 24.7)	21.5 (17.8, 26.8)	0.327
Para / non-para	20 / 42	8 / 12	9 / 13	3 / 17	0.138
anterior located placenta(+ / -)	18 / 44	4 / 16	8 / 14	6 / 14	0.516
delivery weeks	39.2 (37.0, 41.1)	39.0 (37.3, 40.9)	39.1 (37.0, 41.1)	39.4 (37.1, 41.0)	0.649
newborn weight (g)	2990.6 (2340, 3790)	2853.6 (2340, 3404)	3126.8 (2396, 3790)	2977.9 (2400, 3576)	0.067
male / female	30 / 32	8 / 12	10 / 12	12 / 8	0.436
placental weight (g)	573 (400., 790)	525 (400, 730)	594.3 (420, 785)	595.3 (425, 790)	0.070-1.000

Data are presented as number or mean(range).
Comparisons among the three groups were conducted with ANOVA or Tukey-Kramer.

50 cm and more than 60 cm, respectively. Table 1 shows the characteristics of the three groups. Based on SD = 10% and an expected 10% movement difference, we calculated a sample size of 16 women for each group with α = 0.05 and 80% power. The numbers of women in each group were between 20 and 22. The index of movement was then compared among the three groups by ANOVA for the three gestational periods, i.e. 28–31, 32–35, and 36–39 weeks.

All data was analyzed with JMP Pro 12.0.1. The statistically significant difference was set at p value of less than 0.05.

This study was approved by the ethics committee of Teikyo University. All women gave written informed consent before participating in the study.

Results

A total of 2355.6 h from 368 night records were available for this study. Umbilical cord length varied from 35 to 100 cm. The mean length (10–90%) was 54.8 (39.6–69.7) cm. There were no umbilical cord complications, such as a single artery, excessive torsion, no torsion, or velamentous insertion.

Primipara and anterior located placenta were valuables to elongate cord length ($p = 0.013$, and 0.015, respectively), and the placental weight also had positive relationship with cord length ($p = 0.005$); however, there were no relationships between the cord length and the movement index of 28–31, 32–35, and 35–39 weeks ($p = 0.090$, 0.235, 0.129, respectively).

Fig. 1 shows the changes in the index of movements in the shorter, middle, and longer cord groups depending on gestational weeks. In a previous study, we reported normal reference values where the index of movement decreases as pregnancy progresses, with the decrease being relatively rapid around 32–35 weeks [12]. Similar changes are shown in the shorter and middle cord groups; however, the decrease seems to be slight in the longer cord group. Statistical comparisons also demonstrated that there were no differences in the index of movement among the three groups at 28–31 and 32–35 gestational weeks ($p = 0.096$, and 0.465, respectively); however, the longer cord group had a greater index of movement than the other two groups at 36–39 weeks ($p = 0.0008$).

Discussion

The factors determining umbilical cord length are largely unknown. Marpas P [15] reported that little correspondence was found between cord length and the fetal or placental weight. On the contrary, Georgiadis L et al. [16] reported that cord length was associated with birth weight, placental weight, and gestational age. Georgiadia et al. also reported that girls had shorter cords.

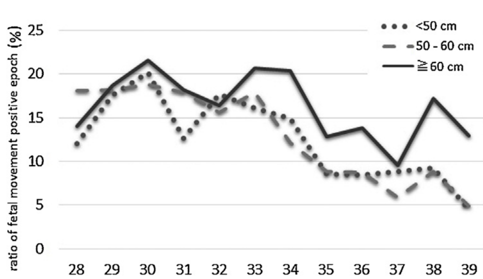

Fig. 1. Changes in the median index of fetal movement in shorter (< 50 cm), middle (50–60 cm), and longer (> 60 cm) umbilical cord groups. There were no differences at 28–31 and 32–35 gestational weeks ($p = 0.096$, and 0.465, respectively). The longer cord group showed more movement than the other two at 36–39 weeks ($p = 0.0008$).

The results of this study demonstrated that there were no correlations found between the cord length at birth and fetal movement counts after 28 weeks; however, the longer cord group had higher fetal movement counts than the other two groups after 36 weeks.

What did these results mean? Positive correlations include both the cord becomes shorter and longer depending fetal movement. Simple explanation could be that decreased fetal movement did not shorten the cord length but increased one elongated that. Actually, there were no differences in the movement index between the shorter and middle cord groups in the results.

In a study by Richard LN [17], the authors noted that umbilical cords progressively grew longer toward term, and the rate of growth gradually slowed. In another study, Georgiadis L et al. [16] also found that umbilical cords grew progressively longer toward term; however, the growth rate was greatest between 31 and 39 weeks, and the maximum growth was at around 35–36 weeks. Both studies were consistent that the umbilical cord continued to grow until term. Continuing grow of the cord seemed to relate our study's results that the group with longer cords had higher fetal movement counts after 36 weeks than the other.

We made normal reference curves for fetal movements in our previous study [12] and demonstrated that fetal movements decreased at around 32–35 weeks; however, the results of this study showed that the decreased fetal movements after that period could be an important factor in finally determining whether or not the umbilical cord becomes longer.

Looking at the changes in fetal movements based on the gestational weeks shown in Fig. 1, we see that fetal movement counts for the three groups were not so different until around 32 weeks. After that, decreases in movement in the longer cord group seemed smaller than those in the other two groups. In the longer cord group, a smaller decrease in fetal movements near term might make the umbilical cord longer and longer as pregnancy progresses, which might eventually make a significant difference in cord length between the longer cord group and the other two.

However, even if this is true, it is still difficult to understand why the shorter cord group did not demonstrate less movement compared with the middle cord group. There are several limitations of this study. One limitation of studies about cord length is that we can measure only final cord length but not the process of cord elongation during pregnancy. Another limitation is that we can count fetal movement only after 28 weeks when the cord length already becomes 2-third of full length.

On top of that, an important problem of this study was that the accuracy of the FMAM recorder has not been fully confirmed. We have discussed about the accuracy of the FMAM recorder in several previous studies [11–14]. Overall, the recorder has a good record of counting fetal movements: however, additional clinical studies are still needed to fully confirm its accuracy. If this study had demonstrated no positive results about relation between fetal movements and cord length, it would have been unclear whether the FMAM recorder was at fault or whether there was truly no relationship between the two. However, this study showed the positive and reasonable result that the group with longer umbilical cords had higher fetal movement counts than the other groups. We feel that this study is one more that supports the accuracy of the FMAM recorder.

Georgiadis L et al. [16] reported that girls seemed to have shorter cords. If true, that raises the question of whether female fetuses move less compared with male fetuses. In a previous study, we compared fetal movement counts between boys and girls and found no difference between the two [12].

In conclusion, this study suggested that fetal movement near term is an important factor in determining whether cord length becomes relatively longer in normal pregnancies.

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Declarations of interest

None.

Conflict of interest

The authors have no conflicts of interest to declare.

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