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Fetal movement counting at home with a fetal movement acceleration measurement recorder: A preliminary report

Eiji Ryo & Hideo Kamata

Department of Obstetrics and Gynecology, Teikyo University, School of Medicine, Kaga, Itabashi-ku, Tokyo, Japan

***Objective*: Fetal Movement Acceleration Measurement (FMAM) recorder was developed to facilitate gross fetal movement counting. The aim was to assess its reliability. *Methods*: Using the recorder, six pregnant women recorded fetal movements by themselves when they slept at their home weekly from 30 weeks to term. The recorder has 2 acceleration sensors; 1 for fetal movement (FM sensor) and another for maternal movement (MM sensor). Before sleeping, each subject attached the FM sensor to her abdomen, and the MM sensor to her thigh. All the recorded data were divided into 10-sec epochs, and presence of fetal movements was judged for all epochs (total epoch). The epoch was judged as positive for movement (positive epoch) when the FM sensor detected abdominal wall oscillations and the MM sensor did not detect maternal movements. The percentage of positive epoch number to total epoch and the maximum consecutive negative epoch number was calculated. *Results*: The mean percentage was approximately 20–25% at 30–34 weeks and 10–15% at 35–38 weeks. The negative epoch number linearly increased after approximately 33–34 weeks of gestation. *Conclusions*: The FMAM recorder was reliable for long-duration recording of gross fetal movements at home.**

Keywords: Capacitive acceleration sensor, fetal movement acceleration measurement recorder, fetal death, fetal monitoring, fetal movement counting, fetal well-being, gross fetal movement, home monitoring

Introduction

Fetal movements are an important biological index to estimate fetal well-being. They are one of the variables of fetal biophysical profile scoring used world-wide [1]. The scoring system has substantially contributed to the field of perinatal medicine; however, it allows qualitative and not quantitative analysis of fetal movements. Furthermore, the scoring system can be used only for a short time in medical facilities and not at home because it involves the use of ultrasonography. Thus, there have been no practical and objective methods for long-duration fetal movement counting.

Nishihara et al. [2] employed a newly developed capacitive acceleration sensor and recorded oscillations of the maternal abdominal wall caused by fetal movements. They demonstrated that oscillations detected by the sensor were strongly correlated with maternal subjective perceptions of fetal movements. By using the newly developed sensor, we have developed a fetal movement acceleration recorder (FMAM recorder, http://e-mother.co-site.jp). The recorder is designed to monitor fetal movements when the mother is sleeping at home. In the previous study [3], we simultaneously observed oscillations of the maternal abdomen by the recorder and gross fetal movements by ultrasonography and demonstrated a high level of consistency between the two instruments. In particular, readings of the 2 instruments were almost perfectly correlated after 30 weeks of gestation. However, these results were examined during a 30-minute interval when the mothers were asked to keep quiet on a bed at a laboratory. It is still unclear how reliable the recorder is when mothers use it at home by themselves.

The purpose of the study was to assess the reliability of the FMAM recorder at home. For this, we collected fetal movement data obtained by the mothers by using the recorder at home and analyzed whether their results were reasonable.

Methods

FMAM recorder

The FMAM recorder is shown in Figure 1. It contains 2 acceleration sensors and 4 batteries and weighs 290 g. Both the sensors are similar in structures but have different sensitivities. One sensor is a fetal movement sensor (FM sensor) and the other is a maternal movement sensor (MM sensor). When the FM sensor attached to the maternal abdomen detects abdominal wall oscillations and the MM sensor attached to the thigh of the mother does not detect any maternal movements, fetal movements are judged to have occurred. Both the sensor is disk-shaped, 20 g in weight, and 2.8 cm in diameter. The sensor has 2 electrodes with capacitive acceleration, of which 1 is a movable diaphragm, and the other is a fixed backplate. The diaphragm has a slight weight which works as a pendulum; this increases its sensitivity to detect oscillation. A change in acceleration appears as the amount of change of delta C in electrostatic capacity C between the diaphragm and the backplate arising from the displacement of the diaphragm. The sensitivity of the FM and MM sensors was set at 700 mV/0.1 G and 120 mV/0.1G, respectively. The sensors are completely non-invasive.

Fetal movement counting by using FMAM recorder at home

Six pregnant women volunteered to participate in the study and underwent a total of 61 experiments. Table I shows the characteristics of pregnant women participating in this study. None of these mothers had any complications, and all their newborns were delivered at term without anomalies or neurological problems.

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Correspondence: Eiji Ryo, Department of Obstetrics and Gynecology, Teikyo University, School of Medicine, 2-11-1, Kaga, Itabashi-ku, Tokyo 173–8606, Japan. Fax: 81-3-5375-1274. E-mail: yonchi@med.teikyo-u.ac.jp

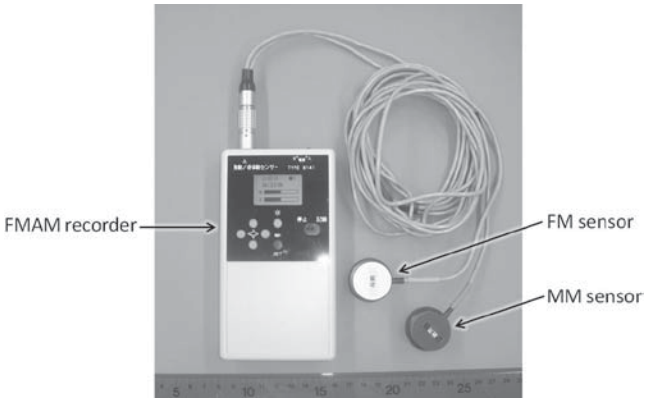

Figure 1. Fetal movement acceleration measurement (FMAM) recorder. It contains 2 capacitive acceleration sensors.

Table I. Characteristics of the pregnant women included in the study.

Case	Mother Age	Para	BMI	Delivery day	New born weight (g)	Sex	UA pH
1	36	0	17.53	39w4d	2740	Male	7.285
2	32	0	21.77	40w6d	2776	Female	7.124
3	30	2	19.48	39w4d	3438	Female	7.297
4	35	0	21.48	39w5d	3266	Female	7.368
5	26	0	19.43	38w1d	2896	Male	7.300
6	34	0	22.89	40w6d	3182	Male	7.269

BMI = Body mass index; UA = Uterine artery.

Each pregnant woman was instructed on how to use FMAM recorder and was allowed to take the device home to record fetal movements by herself; the instruction took approximately 10 min. The batteries of the device can be charged at home, and a record is available during 40 h after 1 charging cycle. Fetal movements were recorded during the night while the mother was sleeping. Each mother was asked to record fetal movements weekly from 30 weeks to term. Just before sleeping, each mother attached the FM sensor to her abdomen and the MM sensor to her thigh by using adhesive tape. Next, they turned on the recorder and fell asleep. The next morning, they would wake up and turned off the FMAM recorder. The data were recorded in a SD card. Each time the mothers visited the hospital for a routine check-up, they would remove the card from the recorder and give it to the researchers. The data from the card were transferred to a computer, and the card was given back to the mother for the next recording period.

Data analyses

All the data transferred to the computer were divided into 10-sec epochs; thus, 360 epochs per h. At first, epoch readings for periods when the MM sensor detected maternal leg movements were deleted from data analysis. Next, all the remaining epochs (total epoch) were reviewed to determine whether gross fetal movements occurred. An epoch was judged to be positive for fetal movements (positive epoch) when an oscillation was detected by the FM sensor and it was larger than that caused by the maternal heartbeat and it was not caused by maternal breathing. Abdominal oscillations caused by maternal heart beat and breathing could be identified by their specific regular pattern. Other epochs were judged to be negative for fetal movements (negative epoch). We are now developing a computer program to analyze the oscillation signals, but it is not yet completed. Therefore, the data of this study was analyzed manually.

Thereafter, the number of positive epochs was counted, and its percentage in relation to the total epoch number in 1 night was calculated. Furthermore, the maximum consecutive negative epoch number during 1 night was counted, which indicated the longest interval of fetal quiescence during the night. If the resulting number was 10, it meant that the longest interval of fetal quiescence was approximately 100 sec.

This study was approved by the ethical committee at Teikyo University. All the participating mothers gave their written informed consent for the study.

Results

All the mothers in the study were able to record the fetal movements every time. The mean (SD) recording time and total epoch number for one night was 6.2 (1.3) h and 2147.2 (442.9), respectively. No negative side effects were noted, except for mild contact dermatitis caused by the adhesive tape. Figure 2 is an example of the resulting record showing fetal and maternal movements during 1 night at a study participant's home. The upper part of the figure shows the general view of maternal and fetal movement during maternal sleep from 1:30 to 6:30 AM. The lower part focuses a 5-min epoch at 2:40 AM. We can see 1 signal of fetal movement and no maternal movement in a circle.

Figure 3 shows the percentage of positive epoch number to total epoch number related to gestational weeks. The mean percentage was approximately 20–25% at 30–34 weeks, and it decreased to approximately 10–15% at 35–38 weeks. Figure 4 shows the maximum consecutive negative epoch number during the entire night. It increased after approximately 33–34 weeks of gestation.

Discussion

The purpose of the study was to assess the reliability of the FMAM recorder at home. The only way to accurate assessment is to simultaneously observe the oscillations of the maternal abdomen by the recorder and fetal movements by ultrasonography when the mother is sleeping the night. However, this cannot be done because of practical difficulties and ethical issues.

As the next option, we collected preliminary data on fetal movements recorded by the mothers themselves and analyzed whether the data were reasonable. We asked the mothers to record fetal movements at home with a FMAM recorder. Its use was simple and easy. All the mothers successfully recorded fetal movements every time by using the provided FMAM recorder. The FMAM recorder was handy, safe, and available at home.

To date, various fetal movements in mothers have been studied through ultrasonography, and several quantitative assessments of fetal gross movements have been reported. Patrick et al. [4] studied 10 fetuses at 34–35 weeks and reported that the mean percentage time during which gross movement existed was 8.2%. In another report, Patrick et al. [5] described mean percentage gross movement times of 9.3%, 9.8%, and 11.2% at 30–31, 34–35 and 38–39 weeks, respectively. The same group [6] studied 28 fetuses at 38–40 weeks of gestation, and showed a mean percentage gross movement time of 12.2% for fetuses delivered within 3 days and 11.6% for fetuses delivered >7 days after the study. Similarly, Ten Hof et al. [7] studied 29 fetuses between 24 and 36 weeks and found that the median percentage time during which fetal body movements existed was 17% at 24 weeks and 7% at near term. Furthermore, in a study on 15 fetuses by D'Ellia et al. [8], the median incidences of body movements at every 60-min interval were 50, 43, and 34

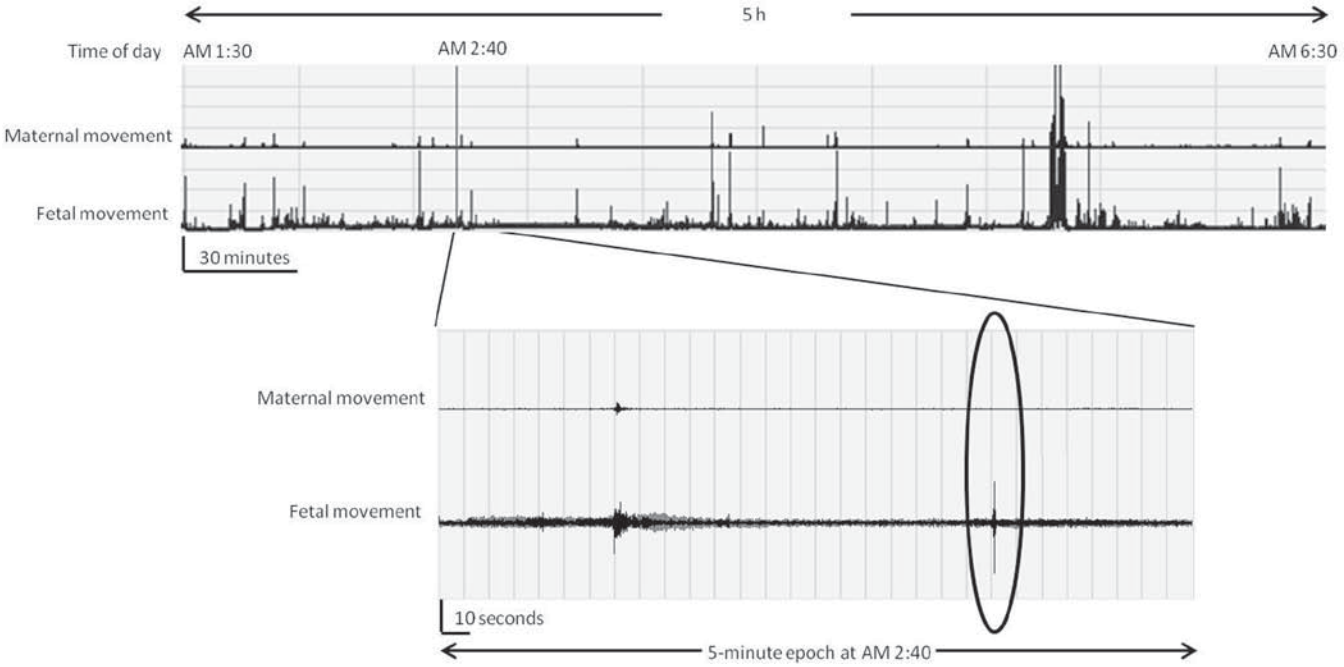

Figure 2. An example of the record showing fetal and maternal movements at a study participant's home. The upper part of the figure shows a general view of maternal and fetal movements during the entire night from 1:30 to 6:30 AM. The lower part focuses a 5-minute epoch at 2:40 AM. We can see 1 signal of fetal movement and no maternal movement in a circle.

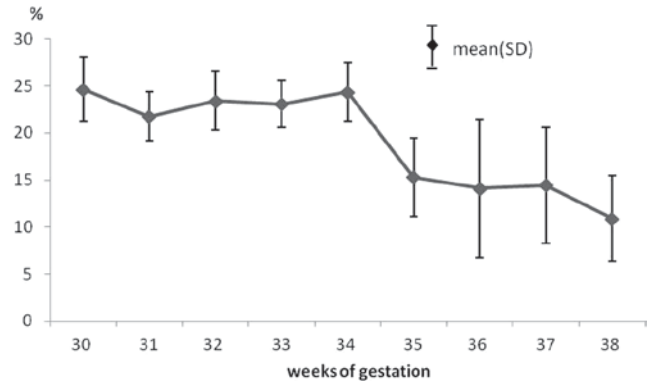

Figure 3. The percentage of positive epoch number to total epoch number associated with gestational weeks.

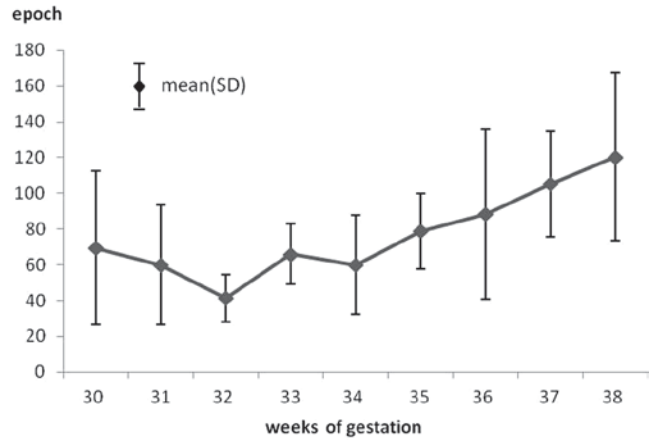

Figure 4. Maximum consecutive negative epoch number during 1 night associated with gestational weeks.

at 28, 34, and 38 weeks, respectively, and their median duration times were 9.4, 7.15, and 7.2 sec, respectively. By multiplying these figures, they obtained duration times of 470, 307, and 245 sec, respectively, and their percentages at 60-min intervals were approximately 13%, 8.5%, and 7%, respectively. These studies showed the mean and median rate of time during which gross fetal movements existed at near term was constantly around 10%. On the other hand, the mean percentage gross movement times for women at earlier stages of pregnancy were different depending on the reports; however, the values were same as those at term or approximately twice larger than those at term.

In our study, the number of positive epochs was counted, and their ratio to the total epoch number of epochs was calculated; however, the resulting figure was not precisely equal the duration of gross fetal movements. Even when a short movement caused abdominal wall oscillation, one 10-sec epoch was counted as positive. When a fetal movement crossed over 2 epochs, two 10-sec epochs were counted similarly. In the study by D'Ellia et al. [8], the median duration of gross fetal movements was approximately 7 sec at near term. With these considerations in mind, the rate of the positive epoch number should be larger than the rate of time during which gross fetal movements exist but should not exceed twice the largest. In our study, this figure was around between 10% and 20% at term of pregnancy, which is consistent with the previous studies.

Regarding earlier stages of pregnancy, our results showed that the positive epoch number rate was approximately twice larger than that at term, which was consistent with some previous reports.

It is known that the states of fetal behavior become established during late pregnancy, and that the fetal resting state is prolonged as pregnancy progresses [9]. Pillai et al. [10] reported the longest interval of quiescence of fetal movements, which increased linearly with advancing gestational age after approximately 30 weeks. The results of our study showed that the maximum consecutive negative epoch number during the night also increased linearly

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as pregnancy progressed, which was very similar to the results obtained by Pillai et al.

In summary, the number of gross fetal movements counted by FMAM recorder at home in our study appeared reasonable compared with the previous reports.

In general, it is difficult to confirm the reliability of new data, which can be obtained only by a novel method because no alternative methods can provide such confirmation. In the previous study done at a laboratory [3], we simultaneously observed maternal abdomen oscillations and gross fetal movements by using FMAM recorder and ultrasonography, respectively. The agreement between the two proved to be substantial at 20–29 weeks and almost perfect at 30–39 weeks, and it was higher at a latter stage of pregnancy than that at an earlier one. These are probably because the strength of fetal movement increases with fetal developments. In this study, fetal movements were recorded by pregnant women in their own homes after 30 weeks of gestation, and their numbers were shown to be reasonable compared to the previous studies. As a preliminary study, we think that the FMAM recorder can be relied upon for accurate gross fetal movement counting after 30 weeks of pregnancy. However, some factors such as maternal obesity and polyhydroamnios might decrease the reliability of the recorder. There are few data about that. The reliability of the recorder should be re-evaluated after more dater is later obtained.

In conclusion, the FMAM recorder is reliable for counting gross fetal movement after 30 weeks of pregnancy when the mother is asleep for long duration of time.

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***Declaration of Interest*:** The authors declare no conflict of interest.

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