0889-8545/99 $8.00 + .00

FETAL MOVEMENT COUNTS

Franklyn C. Christensen, MD, and William F. Rayburn, MD

The concept of monitoring fetal whole body movements has existed for more than a century. Early knowledge of fetal neurologic function was based on maternal perception of aborted fetuses and systematic studies of newborn infants.[17, 18, 27] Information concerning how the fetus moves and on quantitative and qualitative movement patterns during gestation has become available in the last few decades. Real-time ultrasound has allowed a quality assessment of the comprehensive motor repertoire in healthy and undisturbed fetuses in their natural environment. This information has enabled characterization of fetal movements in growth-restricted fetuses and those with congenital malformations.

This article addresses the monitoring of fetal kicks, focusing on methods to record and classify different activities. The relationship between fetal movement and simultaneous fetal heart rate (FHR) accelerations and external stimuli is described, especially in relation to a cascade of fetal testing. Limitations to fetal kick counts and future perspectives are discussed.

MONITORING TECHNIQUES

Methods to monitor fetal movement range from charting maternally perceived movements to sophisticated methods requiring specialized equipment operated by skilled professionals, such as real-time ultrasonography, Doppler ultrasound, and electronic FHR monitoring.

From the Department of Obstetrics and Gynecology, Division of Maternal-Fetal Medicine, University of New Mexico School of Medicine, Albuquerque, New Mexico

Maternal Perception

Perceived fetal motion by a compliant gravida is the simplest and least expensive technique for monitoring fetal well-being in the second half of pregnancy. It requires no monitoring devices or laboratory procedures. Independent studies have reported a significant positive correlation between maternal perception of fetal movement and movements confirmed by ultrasound scanning from 28 to 43 weeks of gestation.[11, 15, 39]

Several methods for charting fetal kick counts have been described and are listed in Table 1. The most attractive method is the "count to 10" technique.[37] This technique is simple and can be performed at any convenient time. Table 2 shows an example of a "count to 10" chart. Patients can provide a "report card" for the fetus relatively easily by noting whether the fetus received an A, B, C, D, or, rarely, F rating. F ratings should be evaluated with further testing; the woman should contact her health care provider for specific instructions.

The patient should be encouraged to lie on her left side and to concentrate on fetal activity. For most women, evening hours may be most convenient. A recent meal or juice intake is not necessary because gross fetal body movements are unaffected by maternal glucose levels.[39] This observation also applies to pregnant diabetic women. Fetal limb and body movements, breathing movements, heart rate, and Doppler velocity waveforms are not affected by maternal glucose levels as low as 45 mg/dL.[42]

Table 1. TECHNIQUES FOR MONITORING PERCEIVED FETAL MOTION

Study (year)	Definition of Decreased Fetal Activity	Recording Periods
Pearson and Weaver (1976)[31]	<10 Movements/12 h	12 Hours (9:00 AM to 9:00 PM) daily
Sadovsky and Polishuk (1977)[44]	<2 Movements/h	30 Minutes to 1 hour, twice or three times daily
Neldham (1980)[29]	≤3 Movements/h	One 2-hour period, three times weekly
O'Leary and Andrinopoulos (1981)[30]	0–5 Movements/30 min for each of the three 30-minute periods	Three 30-minute periods, daily
Harper et al (1981)[13]	Complete cessation	Three 1-hour periods, daily
Leader et al (1981)[21]	1 Day of no movements or 2 successive days/ week in which there are <10 movements/h	30 minutes, four times daily
Rayburn (1982)[37]	≤3 Movements/h for 2 consecutive hours	≥1 Hour (when convenient)
Picquadio and Moore (1989)[32]	<10 Movements/h for 2 consecutive hours	Count to 10 movements (no time restrictions)

Table 2. AN EXAMPLE OF A "COUNT TO 10" FETAL KICK COUNT CHART

Week	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	A B C D F	A B C D F	A B C D F	A B C D F	A B C D F	A B C D F	A B C D F
	A B C D F	A B C D F	A B C D F	A B C D F	A B C D F	A B C D F	A B C D F
	A B C D F	A B C D F	A B C D F	A B C D F	A B C D F	A B C D F	A B C D F
	A B C D F	A B C D F	A B C D F	A B C D F	A B C D F	A B C D F	A B C D F
	A B C D F	A B C D F	A B C D F	A B C D F	A B C D F	A B C D F	A B C D F
	A B C D F	A B C D F	A B C D F	A B C D F	A B C D F	A B C D F	A B C D F
	A B C D F	A B C D F	A B C D F	A B C D F	A B C D F	A B C D F	A B C D F
	A B C D F	A B C D F	A B C D F	A B C D F	A B C D F	A B C D F	A B C D F

To know more about your baby, we ask you to count how many minutes it takes you to feel 10 distinct movements (kicks, stretches, or rollovers—not hiccups). Do this anytime while lying on your side. Circle the letter corresponding to the number of minutes.

A = 0–15 minutes; B = 16–30 minutes; C = 31–45 minutes; D = 46–60 minutes; F = >60 minutes.

Contact us at (   )   (9:00 am–4:30 pm on weekdays) or (   )   (weeknights and weekends) if more than 1 hour is needed to feel 10 movements. Otherwise, please bring this chart with you at your next visit.

The patient should be clearly instructed regarding the specific technique of recording fetal movement counts. The importance of recognizing decreased fetal activity must be stressed. Most women are compliant when they understand the rationale for fetal monitoring and are informed that the procedure usually requires no more than 1 hour a day.[48] Continued encouragement by a consistent health care professional may be necessary.

Fetal movement counts recorded by the pregnant woman may enhance maternal-fetal bonding. Having the father help with charting may also prove useful in the family attachment process and in some cases may augment compliance. The small number of women who are incapable of recording fetal movement often improve their perceptive ability when instructed during ultrasound examinations.

Ultrasound Imaging

Ultrasound techniques permit a direct observation of fetal movement over extended periods of time without disturbing the fetus. High-resolution, real-time ultrasound allows observation of specific movement patterns.[33] Two-dimensional images can be produced by placing an ultrasound transducer, usually 3.5 MHz, on the maternal abdomen along the axis of the fetal thorax and abdomen. Two transducers used simultaneously to visualize the whole fetus during the second trimester have been used for research purposes. A 5- to 30-minute observation period is commonly considered to be adequate. The frequency, intensity, and duration of fetal movements are correlated with maternal perception of the movements. Some movements of lesser duration or intensity observed during an ultrasound examination are not perceived by the pregnant woman.

Although ultrasound assessment of spontaneous gross body movements is important as a diagnostic index of fetal well-being, the underlying morphologic substrate of these movements and their functional significance during prenatal life are understood less clearly. This lack of knowledge is related in part to limited information regarding the ultrastructure of the central nervous system and muscles in the fetus, particularly synapse and motor end plate formation. Shortcomings of ultrasound investigations of fetal movement patterns and their developmental course relate to the relatively short duration of observation (usually only a few minutes) and the lack of repeated observations.

Comparisons of longitudinal observations of fetal behavior with the well-established patterns of postnatal behavior in low-risk premature infants have revealed striking similarities between fetal and preterm infant behaviors at the same conceptional age.[16] Identical movement patterns in the fetus may be observed after birth, along with certain specific movements that represent an apparent adaptation to the extrauterine environment, such as the Moro reflex. The terminology used to describe movement patterns in the newborn may be applied before

birth.[34] The reduced effect of gravity in utero may cause a more gradual drop of an elevated limb. Similarly, anteflexion of the head or rotation of the body, which is normally observed at the age of 3 to 4 months, may be observed in utero because of the buoyancy effect of amniotic fluid.[2]

Doppler Ultrasound

Fetal movement may be documented by Doppler ultrasound. Limb and trunk movements can be recorded with very low frequency signals by passing the Doppler signal through a band filter,[46] whereas unprocessed raw signals may impede the analysis of movement. Electronic monitoring systems are commonly used for the continuous automatic, time-synchronous recordings of gross fetal body movements and heart rate. The Doppler device, Hewlett-Packard M-1350-A (Boeblingen, Germany), has been reported to record 94% of isolated limb movements, 95% of spinal flexion and extension movements, 97% of rolling movements, and 100% of complex combined movements observed by ultrasound.[26]

In a study comparing a new fetal movement algorithm (Russell algorithm)[22] with the Hewlett-Packard M-1350-A system, second-by-second review of videotaped real-time images was performed to assess the ability of both Doppler devices to define fetal movements. When these devices are used, neither time nor signal strength can be used to separate movement types. Both systems fail to define adequately the duration of movements. Long fetal movements are usually recorded as many smaller length movements, whereas short discrete movements are inefficiently detected.

Fetal Heart Rate Monitoring

Fetal movement and the onset of FHR accelerations are synchronized and coordinated functions.[38] Doppler and real-time ultrasound studies have shown an association between fetal trunk movement and the FHR pattern. Adequate accelerations (>15 beats per minute and lasting ≥15 seconds) have been reported in association with 79% of fetal movements felt by the pregnant woman and 99% of fetal movements seen sonographically.[36] Smaller accelerations are correlated with 53% of perceived movements and 82% of those recorded by ultrasound. A reduced incidence of nonreactive nonstress test (NST) results has been associated with NST and Doppler-detected fetal movements.

Vibration is a potent stimulus to elicit changes in fetal movements and heart rate. An electrolarynx firmly applied to the maternal abdomen and having an output of approximately 110 dB in a frequency range of 250 to 850 Hz can produce a vibroacoustic stimulus.[8] When the stimulus is applied for at least 3 seconds to a normal fetus during behavioral state I,F (when the FHR variability, body movements, and eye movements are

the least), an abrupt increase in fetal movements is observed and may last for an hour.[10] The fetal response consists of a startle reaction characterized by a head aversion, arm movement, and leg extension. It may be concluded that the abrupt heart rate changes and the prolonged episodes of vigorous fetal activity are *fetal startle responses.* Vibroacoustic stimulation has been suggested as a test for fetal well-being during periods of low heart rate reactivity owing to reduced motor activity. Fetal movement in response to stimulation has been reported to correlate with umbilical blood pH values of 7.20 or greater in situations in which FHR monitoring is not informative.[7]

Evidence that the near-term fetus can hear has been offered for many years, and several systematic and well-controlled studies have shown a state dependence similar to that in the newborn infant.[33] In a randomized controlled trial using acoustic stimulation, 89% of fetuses had increased body movement, and stimulation was associated with a reactive NST in 99% of cases.[24]

FETAL MOVEMENT PATTERNS

An obvious distinction between body movements can be based on the amplitude and speed of the activity (e.g., weak versus strong, short versus sustained) involving either the whole body or limbs only. Table 3 describes different types of observed fetal movement using this distinction. Although this type of characterization has been used since Reinold's pioneer work,[43] the complexity of movements exceeds the limited discrimination power of such categories.

A more systematic approach has been described by DeVries and colleagues[4] within the conceptual context of developmental neurology. The investigations performed by these researchers were preceded by a longitudinal study of strictly selected, low-risk preterm infants by Prechtl and co-workers[35] chosen "because they are the only group whose

Table 3. CHARACTERIZATION OF FETAL WHOLE BODY MOTION DURING THE SECOND HALF OF GESTATION

Rights were not granted to include this data in electronic media. Please refer to the printed journal.

From Rayburn WF: Antepartum fetal assessment: Monitoring fetal activity. Clin Perinatol 9:1–14, 1982; with permission.

behavior can be compared, with any meaning, with the recorded behavior of the intrauterine fetus during undisturbed pregnancies." Repeated observations of fetuses selected carefully from low-risk pregnancies were videotaped on a longitudinal basis for 1 hour during the second trimester and for 2 hours during the third trimester. The fetal movements were defined as described by Prechtl (see box).[33]

ULTRASONIC CHARACTERIZATIONS

Startles are quick generalized movements that always begin in the limbs and often spread to the trunk and neck. The duration of a startle is 1 second or less. Usually, these movements occur singly, but sometimes they may be repetitive. Startles can be superimposed incidentally on a general movement.

General movements are also gross movements but are slow and involve the whole body. They may last from a few seconds to a minute. A peculiarity of these movements is the indeterminate sequence of arm, leg, neck, and trunk movement. The movements wax and wane in intensity, force, and speed. Despite this variability, they must be considered as a distinct pattern and easy to recognize if they occur again.

Hiccups are phasic contractions of the diaphragm, often repetitive at regular intervals. A bout of hiccups may last as long as several minutes. In contrast to the startle, the movement always starts in the trunk but may be followed by involvement of the limbs.

Fetal breathing movements are usually paradoxical. Every contraction of the diaphgram (which after birth leads to an inspiration) causes an inward movement of the thorax and a simultaneous movement of the abdomen outward. The sequence of "breaths" can be either regular or irregular. No amniotic fluid enters the lungs during breathing movements. Isolated breaths may resemble a sigh.

Isolated arm or leg movements may occur without other parts moving. The speed and amplitude of the movement may vary.

Twitches are quick extensions or flexions of a limb or the neck. They are never generalized and are not repetitive.

Clonic movements are repetitive tremulous movements of one or more limbs at a rate of approximately three per second. There are rarely more than three to four beats in normal fetuses.

The total repertoire of fetal movements consisted of motor patterns that also were observed after birth. Although the newborn's behavior rapidly expands, with certain patterns not observed in the fetus, the striking similarity between fetal movements and postnatal motor patterns greatly facilitates a consistent and comprehensive descriptive classification and terminology.

It is generally accepted that monitoring fetal motion is useful in predicting fetal compromise; therefore, one must be aware of fetal movement patterns as they change with gestational age. Fetuses studied from

20 weeks' gestation to term displayed progressively slower heart rates, increased heart rate variability, reduced but more vigorous motor behavior, coalescence of heart rate and movement patterns into distinct behavioral states, and increased cardiac responsivity to stimulation with advancing gestation.[5] Qualitative and quantitative measures of fetal activity do not decrease in the week before delivery.[39] This observation dispels the common belief that a sudden loss or decrease in movement is predictive of impending labor.

FETAL TESTING CASCADE

The compromised fetus decreases its oxygen requirements by reducing activity. Documented cessation of activity warns of impending death.[32, 37, 44] A reduction in activity is more often associated with complications of chronic rather than acute fetal distress. Approximately one-half of inactive fetuses are stillborn, tolerate labor poorly, or require resuscitation at birth.[37]

Perceived fetal kick counting has become a useful adjunctive test for fetal assessment in high-risk pregnancies. Its application to low-risk pregnancies is attractive because approximately half of stillbirths occur without obvious cause in normal pregnancies.[32, 37] Although such applications may be beneficial, questions regarding patient acceptability, the need for further fetal testing, and the perinatal implications of unwarranted intervention must be answered before the universal application of fetal movement counting protocols can be recommended.

If a patient reports fetal inactivity lasting more than 1 hour, her perception should be confirmed. Any underlying complication must be evaluated, and fetal well-being should be assessed by a more precise means such as electronic FHR monitoring or ultrasound (the biophysical profile). The authors recommend prompt examination within 12 hours from the woman's perception of fetal inactivity. The findings must be carefully explained to the patient so that she does not experience undue anxiety.

The patient reporting fetal inactivity according to the charting technique should be queried as to whether she rested and concentrated on counting. If the patient remains uncertain regarding the inactivity, she should be instructed to count for 1 more hour and to notify the physician again if too few movements are felt. When the cessation of fetal movements is perceived, confirmation and further fetal evaluation should be initiated. A NST is an appropriate first step in evaluating these patients. In women with low-risk pregnancies, a reactive FHR tracing is predictive of a good outcome in approximately 93% of cases[6]; however, it is not unusual to detect oligohydramnios when decreased fetal movements persist. If the NST is nonreactive, a contraction stress test or a biophysical profile for direct visualization with real-time ultrasonography is necessary. Ultrasonography has advantages over Doppler ultrasound recordings, which do not allow the recognition of specific movement

patterns. Ultrasonography may also provide an opportunity to confirm fetal cardiac motion, to search for major malformations, and to semiquantify amniotic fluid volume.

If a vigorous fetus is confirmed, movement charting should be encouraged unless the patient feels uncomfortable relying on this method of surveillance. A lack of body movement during sonographic observation may warrant vibroacoustic stimulation testing. A vibroacoustic stimulus–evoked fetal startle response observed under ultrasonography has been described as a good predictor of a biophysical profile score equal to or greater than 8 in almost all cases.[45] Further biophysical profile testing or delivery may be indicated depending on the clinical situation. The diagnosis of fetal death necessitates delivery for meticulous examination of the stillborn infant, umbilical cord, and placenta.

LIMITATIONS

Although monitoring fetal body movement permits a general assessment of well-being, no technique is infallible. Limitations include expense, equipment, the failure to anticipate certain fetal deaths, the effects of maternal drugs, the effects of maternal exercise, and the failure to predict fetal malformations and growth abnormalities.

Expense and Patient Convenience

Optimal assessments of fetal well-being require continuous monitoring of movement. Monitoring often requires evaluation for 30-minute periods or longer with costly equipment (ultrasonography, FHR monitors, Doppler ultrasound) operated by skilled professionals. Consequently, monitoring is usually performed only weekly or semiweekly once the pregnancy has reached a critical stage at which extrauterine survival is probable and delivery is an acceptable option. The daily perception of fetal activity has certain advantages; however, expecting the pregnant woman to monitor the fetus for more than 1 hour per day for long periods can lead to compliance problems.

Failure to Anticipate Certain Stillbirths

No technique of fetal surveillance can anticipate all stillbirths. When movement patterns have been reassuring, the low proportion of unfavorable outcomes is usually related to acute hypoxic changes, presumably from an umbilical cord compression or placental abruption.[12, 37] An autopsy often shows no obvious abnormalities. On careful questioning, the patient frequently describes a sudden loss of perceived movement shortly before fetal death is confirmed.

Failure to Detect Growth Abnormalities

Although reduced fetal movement patterns may improve the prediction of stillbirth, they are not useful for detecting most growth abnormalities. Growth-restricted fetuses exhibit significantly lower fetal activity rates than normally growing fetuses at all gestational ages when evaluated consistently by ultrasound,[50] despite the fact that fetal activity may be perceived as normal by the gravida. Diminished activity can be anticipated in only the most severe cases, such as fetuses in the lower fifth percentile for expected birth weight.[25] When sonography confirms that a fetus is small for gestational age, an underlying medical, genetic, metabolic, or chronic inflammatory process should be considered. The activity patterns of fetuses that are large for gestational age are thought to be indistinguishable from the activity patterns of appropriately sized fetuses.

Failure to Detect Malformations or to Predict Outcome in Their Presence

Most fetuses with congenital anomalies have perceived movement patterns that are not different from the patterns produced by normal fetuses. Only a few malformations or fetal conditions affect fetal movement. Excessive fetal activity (an average of $\geq$40 perceived motions per hour for at least 14 days[41]) may represent a fetal anomaly such as anencephaly. Abnormal movement mimicking fetal convulsions, subsequently found to be decerebrate hypertonicity in a brain-dead fetus, has been described.[19] A lack of vigorous motion may relate to abnormalities of central nervous system pathways or, less commonly, to muscular dysfunction, skeletal abnormalities, or mechanical restriction of the lower extremities. Inactivity has been documented in fetuses with major malformations such as hydrocephalus, bilateral renal agenesis, and bilateral hip dislocation.[40] A malformation should be considered when activity is not perceived in the presence of oligohydramnios or polyhydramnios.

Fetal movement counting has not been useful in describing the ontogeny of fetal movements or in predicting outcome in the presence of malformations. Sonographic studies can improve understanding about the development of the central nervous system as it relates to the formation of fetal movements. Weekly recordings comparing a normal and an anencephalic fetus in a twin pregnancy have suggested that the development of the central nervous system above the medulla oblongata has an important role in the elimination of fetal movements such as startle and writhing and in the commencement of breathing movements.[20] In the fetus with an open neural tube defect, fetal kicks may be perceived as normal by the pregnant woman. Leg movements below these lesions seem to be of normal quality and endogenously generated when assessed with real-time ultrasound. Longitudinal follow-up of

these fetuses reveals that fetal and early neonatal leg movements are not predictive of postnatal motor function; however, early sensory function is strongly related to the level of the open spinal defect and accurately predicts final motor outcome in most cases.[47]

Failure to Distinguish Between Twins

No monitoring technique consistently distinguishes between twin fetuses on a daily basis. Videotaped recordings of twin pregnancies show that contacts between fetuses that produce movement by the other twin may begin as early as 11 weeks' gestation or even earlier if twinning is monochorionic rather than dichorionic.[1] Ultrasound imaging often shows *boxing matches* that last a few minutes and that are separated by rest periods; this type of activity may explain why the whole body movements of twins are thought to be more frequent than those of singletons.[9] The patient's perception that both fetuses are active is reassuring; however, the patient frequently reports that one fetus is less active than the other.

Limitations with Doppler Ultrasound

Doppler ultrasound cannot distinguish between types of body movements or detect subtle movements. Single or cluster recordings of movements reflect isolated kicks or more coordinated trunk and extremity movements such as stretches or rollovers.[26] Small movements may remain undetected. As is true for maternal perception, Doppler ultrasound cannot detect fetal activity such as rapid eye, breathing, and hand movements. In addition to missing certain forms of movement, Doppler ultrasound can record unwanted signal artifacts, usually caused when the woman moves or the Doppler beam is repositioned. Experience in recognizing such artifacts and reducing such extraneous movement helps the clinician determine which recordings actually indicate fetal body movement.

Maternal Exercise

Pregnant women frequently seek advice from their physicians regarding the safety of exercise during pregnancy. In most low-risk pregnancies, exercise is considered safe. While exercising, the pregnant woman should not feel short of breath, thus avoiding exhaustion and an anaerobic state. Hypoglycemia should be avoided at all times. Hyperthermia can be dangerous, especially in the first trimester, because it may be associated with neural tube defects and impaired brain development.

One ultrasonographic study of the effects of maternal exercise (20 minutes of aerobic dance) on fetal behavior in late gestation showed a

significant decrease in fetal breathing but no significant change in shoulder movement or kick response.[14] Because the effects of low-impact exercise on the fetus are mild and transitory, fetal kick counting immediately after this type of activity is not necessary.

Heavy exercise clearly affects the fetus and is associated with signs of transient fetal impairment.[23] In 12 healthy women, fetal body movements were negatively correlated with the percentage of maximal increase in heart rate. FHR and breathing movements decreased significantly when the maximal increase in maternal pulse exceeded approximately 90%. At this level of cardiac stress, two cases of fetal bradycardia were reported, followed by reduced FHR variability and the absence of body and breathing movements for 20 minutes. The physician should counsel the high-risk gravida to avoid excessive exercise and hyperthermia.

Effects from Medications

Sedating drugs such as alcohol, barbiturates, narcotics, methadone, or benzodiazepines are known to cross the placenta. Significantly more NSTs are nonreactive or take longer to become reactive in the methadone-maintained gravida. Biophysical profile scores are reported to be the same before and after methadone dosing in 75% of women.[3] Altered behavior is expected to reverse after clearance of the drug.

Possible effects of maternal antiepileptic medication on fetal movement have been examined between 32 and 38 weeks' gestation.[49] No marked differences in patterns of fetal motion and heart rate were described, and no obvious effect on fetal neuromuscular development could be found.

Changes in fetal activity have been observed in patients receiving the corticosteroids betamethasone and dexamethasone. Mulder and coworkers[28] have reported that on the second day following betamethasone administration, FHR variability was reduced by 20%, and body and breathing movements were reduced by 49% and 85%, respectively. All values returned to normal by day 4, indicating a transient effect from the corticosteroid. This information can be useful when counseling pregnant women regarding the use of betamethasone to promote fetal lung maturation.

SUMMARY

Monitoring fetal movement serves as an indirect measure of central nervous system integrity and function. The coordination of whole body movement in the fetus, which requires complex neurologic control, is similar to the coordination of movement in the preterm newborn infant. Short-term observations of the fetus are best performed using real-time ultrasound imaging or Doppler ultrasound. Daily fetal kick counting by

the compliant gravida is a worthwhile adjunct in determining the need for fetal surveillance tests in the office and in predicting abnormal FHR patterns and perhaps impending stillbirth. Monitoring has its greatest value when placental insufficiency is long-standing; its routine role in low-risk pregnancies requires further clinical investigation. The presence of a vigorous fetus is reassuring. Perceived inactivity requires a reassessment of any underlying antepartum complication and a more precise evaluation by FHR testing or real-time ultrasonography before delivery is considered.

References

1. Arabin B, Bos R, Rijlaarsdam R, et al: The onset of interhuman contacts: Longitudinal ultrasound observations in early twin pregnancies. Ultrasound Obstet Gynecol 8:166–173, 1996
2. Birnholz JC, Stephens JC, Faria M: Fetal movement patterns: A possible means of defining neurological developmental milestones in utero. AJR Am J Roentgenol 130:537–540, 1976
3. Cejtin HE, Mills A, Swift EL: Effects of methadone on the biophysical profile. J Reprod Med 41:819–822, 1996
4. DeVries JIP, Visser GHS, Prechtl HFR: The emergence of fetal behaviour. III. Individual differences and consistencies. Early Hum Dev 16:85–103, 1988
5. DiPietro JA, Hodgson DM, Costigan KA, et al: Fetal neurobehavioral development. Child Dev 67:2553–2567, 1996
6. Dubiel M, Gudmundsson S, Thuring-Jonsson A, et al: Doppler velocimetry and nonstress test for predicting outcome of pregnancies with decreased fetal movements. Am J Perinatol 14:139–144, 1997
7. Elliot JP, Clewell WH, Hutson E: Fetal recoil during labor to evaluate fetal well-being when heart rate monitoring is not informative. Obstet Gynecol 89:800–802, 1997
8. Fox HE, Badalian SS: Fetal movement in response to vibroacoustic stimulation: A review. Obstet Gynecol Surv 48:707–713, 1993
9. Gallagher MW, Costigan K, Johnson TR: Fetal heart rate acceleration, fetal movement, and fetal behavior patterns in twin gestations. Am J Obstet Gynecol 167:1140–1144, 1992
10. Gelman SR, Wood S, Spellacy MN, et al: Fetal movements in response to sound stimulation. Am J Obstet Gynecol 143:484–485, 1982
11. Gettinger A, Roberts AB, Campbell S: Comparison between subjective and ultrasound assessments of fetal movement. BMJ 2:88, 1978
12. Grant A, Elbourne D, Valentin L, et al: Routine formal fetal movement counting and risk of antepartum late death in normally formed singletons. Lancet 2:345–349, 1989
13. Harper RG, Greenber M, Farahani G: Fetal movement, biochemical and biophysical parameters, and the outcome of pregnancy. Am J Obstet Gynecol 141:39–42, 1981
14. Hatoum N, Clapp JF 3rd, Newman MR, et al: Effects of maternal exercise on fetal activity in late gestation. J Matern Fetal Med 6:134–139, 1997
15. Hertogs K, Roberts AB, Cooper D, et al: Maternal perception of fetal motor activity. BMJ 2:1183–1185, 1979
16. Hill A, Volpe J: Fetal Neurology. New York, Raven Press, 1989
17. Hooker D: The Prenatal Origin of Behaviour. Lawrence, KS, University of Kansas Press, 1952
18. Humphrey T: Function of the nervous system during prenatal life. *In* Stave U (ed): Perinatal Physiology. New York, Plenum, 1978
19. James SJ: Fetal brain death syndrome—a case report and literature review. Aust N Z J Obstet Gynaecol 38:217–220, 1998
20. Karauchi O, Ohno Y, Mizutani S, et al: Longitudinal monitoring of fetal behavior in twins when one is anencephalic. Obstet Gynecol 86:672–674, 1995

21. Leader I, Baillie P, Van Schalkwyk DH: Fetal movements and fetal outcome: A prospective study. Obstet Gynecol 57:431–436, 1981
22. Lowery CL, Russell WA Jr, Baggot PJ, et al: Time quantified detection of fetal movements using a new fetal movement algorithm. Am J Perinatol 14:7–12, 1997
23. Manders MA, Sonder GJ, Mulder EJ, et al: The effects of maternal exercise on fetal heart rate and movement patterns. Early Hum Dev 48:237–247, 1997
24. Marden D, McDuffie RS Jr, Allen R, et al: A randomized controlled trial of a new fetal acoustic stimulation test for fetal well-being. Am J Obstet Gynecol 176:1386–1388, 1997
25. Mathews DD: Maternal assessment of fetal activity in small-for-dates infants. Obstet Gynecol 45:488–493, 1975
26. Melendez T, Rayburn WF, Smith C, et al: Characterization of fetal body movements recorded on the Hewlett-Packard M 1350-A fetal monitor. Am J Obstet Gynecol 167:700–702, 1992
27. Minkowski M: Nuerobiologische Studien am menschlichen Foetus. Hand Biol Arbeitsmeth Abt.v.Teil 5B:511–616, 1928
28. Mulder EJ, Derks JB, Visser GH: Antenatal corticosteroid therapy and fetal behaviour: A randomised study of the effects of betamethasone and dexamethasone. Br J Obstet Gynaecol 104:1239–1247, 1997
29. Neldham S: Fetal movements as an indicator of fetal well-being. Lancet 1:1222–1224, 1980
30. O'Leary JA, Andrinopoulos GC: Correlation of daily fetal movements and the nonstress test as tools for assessment of fetal welfare. Am J Obstet Gynecol 139:107–108, 1981
31. Pearson JF, Weaver JB: Fetal activity and fetal well-being: An evaluation. BMJ 1:1305–1307, 1976
32. Picquadio K, Moore T: A prospective evaluation of fetal movement screening to reduce the incidence of antepartum fetal death. Am J Obstet Gynecol 160:1075–1080, 1989
33. Prechtl HFR: Fetal behavior. *In* Hill A, Volpe JJ (eds): Fetal Neurology. New York, Raven Press, 1984
34. Prechtl HFR, Nolte R: Motor behaviour of preterm infants. Clin Dev Med 94:79–92, 1984
35. Prechtl HFR, Fargel JW, Weinmann HM, et al: Posture, motility and respiration in low-risk preterm infants. Dev Med Child Neurol 21:3–27, 1979
36. Rabinowitz R, Persitz E, Sadovsky E: The relation between fetal heart rate accelerations and fetal movements. Obstet Gynecol 61:16–18, 1983
37. Rayburn WF: Antepartum fetal assessment: Monitoring fetal activity. Clin Perinatol 9:1–14, 1982
38. Rayburn WF, Motley ME, Zuspan FP: Conditions affecting nonstress tests. Obstet Gynecol 59:490–493, 1982
39. Rayburn WF: Clinical applications of monitoring fetal activity. Am J Obstet Gynecol 144:967–980, 1982
40. Rayburn WF, Barr M: The malformed fetus: Diagnosis and pregnancy management. Obstet Gynecol Annu 14:112–126, 1985
41. Rayburn WF, Rayburn PR, Gabel LL: Excess fetal activity: Another worrisome sign? South Med J 76:163, 1983
42. Reece EA, Hagay Z, Roberts AB, et al: Fetal Doppler and behavioral responses during hypoglycemia induced with the insulin clamp technique in pregnant diabetic women. Am J Obstet Gynecol 172:151–155, 1995
43. Reinold E: Ultrasonics in early pregnancy: Diagnostic scanning and fetal motor activity. Contrib Gynecol Obstet 1:148, 1976
44. Sadovsky E, Polishuk WZ: Fetal movements in utero. Obstet Gynecol 50:49–55, 1977
45. Sarinoglu C, Dell J, Mercer BM, et al: Fetal startle response observed under ultrasonography: A good predictor of a reassuring biophysical profile. Obstet Gynecol 88:599–602, 1996
46. Shinozuka N, Yamakoshi Y: Measurement of fetal movements using multichannel ultrasound pulsed Doppler: Autorecognition of fetal movements by maximum entropy method. Med Biol Eng Comput 31:559–566, 1983
47. Sival DA, Begeer JH, et al: Perinatal motor behaviour and neurological outcome in spina bifida aperta. Early Hum Dev 50:27–37, 1997

48. Smith C, Davis S, Rayburn WF: Patient acceptance of monitoring fetal activity: A randomized comparison of charting techniques. J Reprod Med 37:144–146, 1992
49. Van Geijin HP, Swartjes JM, van Woerden EE, et al: Fetal behavioural states in epileptic pregnancies. Eur J Obstet Gynecol Reprod Biol 21:309–313, 1986
50. Vindla S, James DK, Sahota DS, et al: Computerised analysis of behaviour in normal and growth-retarded fetuses. Early Hum Dev 50:27–37, 1997

Address reprint requests to

Franklyn C. Christensen, MD
Maternal-Fetal Medicine Division
Department of Obstetrics and Gynecology
The University of New Mexico
School of Medicine
2211 Lomas Boulevard NE
Albuquerque, NM 87131–5286