# Acoustical Analysis of Maternal Sounds During the Second Stage of Labor

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Experienced obstetric nurse and midwives indicate they can differentiate among sounds indicating that a woman is (a) beginning to manifest the effort to bear down, (b) experiencing pain, or (c) frightened. This study examined the acoustical properties of work/effort, childlike, and out-of-control utterances to determine whether their acoustical properties differed. Out-of-control utterances are more tense but contain similar levels of shimmer and pitch as childlike utterances. Work/effort utterances are higher pitched and more tense than childlike utterances. Work/effort utterances contain more shimmer but have similar levels of pitch and tenseness as out-of-control utterances.


THE SOUNDS THAT women make during advanced labor, provided they are not masked or altered by medication, are relied on by experienced obstetric nurses and midwives to assess the needs of laboring women. Although these sounds may not be consciously known nor appreciated for their differential meaning or acoustical qualities, they are often of primary significance in communicating to the care provider important information about the woman's labor status or needs. In this study, the acoustical qualities of the sounds recorded during the expulsive phase of labor, late first stage, and the second stage are examined.

Specifically, this study had two aims. The first was to describe the acoustical properties of the following three types of sounds made by women during the latter portion of labor, when uterine contractions are forceful and the baby is descending the birth canal. These utterances are (a) out of control, (b) work/effort, and (c) childlike. The lack of adequate samples of the sound identified by McKay and Roberts (1990) as coping prevented its inclusion in this study. The second aim was to determine if any acoustical property differed among the above three types of sounds.

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## BACKGROUND

### The Significance of Sounds During Labor

During advanced labor constant attendance by the nurse or other caregiver is necessary to provide emotional support and assist the parturient in coping behaviors (Dickason & Schult, 1975; Martin, 1978). The transition from first to second stage is not always clearly defined. A variety of signs or indicators are described in obstetric nursing and nursing diagnosis textbooks (Carlson, Craft, & McGuire, 1982; Jensen & Boback, 1980, 1985; Ziegel & Cranley, 1984). Traditionally, the onset of second-stage labor is defined as complete dilation of the cervix os, but many caregivers find this to be an artificial indicator and watch for behavioral changes in the laboring women to indicate the progression to second-stage bearing down.

As one behavioral indicator of normal progress, experienced obstetric nurses and midwives indicate they can distinguish between sounds according to their quality, pitch, feeling state, and accompanying verbalizations. These care providers claim they can differentiate among sounds indicating that a woman is (a) progressing in labor and beginning to manifest the effort to bear down or

"push" with uterine contractions, (b) experiencing pain, or (c) frightened. The woman's vocal expressions, the tone of her voice, along with her look or manner during contractions or muscular tension in any part of her body, are critical aspects among the behavioral cues that are the basis for providing nursing care (Wiedenbach, 1974).

For example, a nurse-midwife in describing how she relies on the sounds she hears when caring for women during advanced labor said:

> It's (sounds) a common cue that I use. Part of my style is that I don't examine people very often. And I look and listen for the behavior . . . sounds . . . and do a lot of things without checking them (doing a vaginal exam). . . . I'll assume they're in second stage when I hear that real push . . . and not necessarily go back and check them (Roberts & McKay, 1990).

Another nurse commented on the sounds she heard a woman make during labor by saying, "It's crying . . . next thing I'm probably going to do is try to calm her down just a little bit." This nurse explained that just as a mother could distinguish a "hurt" from a "hunger" cry from a baby, she could distinguish the woman who was progressing in labor without distress from the woman who was "scared" and "going to lose control." Mothers, too, seem to be able to identify the meaning of sounds they make during labor. A woman who had recently given birth and viewed a videotape of the event said, "I sound distressed" (McKay & Roberts, 1990). When the interviewer (McKay) asked, "What tells you that?", the mother responded "Just the . . . kind of whining and the high pitch . . . of the voice." Thus, a distinction is made between the verbal and nonverbal cues that suggest that a women is anxious or frightened and those cues that indicate that labor is progressing to the expulsive or second stage.

These and other interviews concerning the sounds women make during the second stage of labor enabled McKay and Roberts (1990) to categorize these sounds as belonging to one of the following maternal states: "work/effort," "coping," "childlike," "out of control," and "with epidural anesthesia." These authors maintain that the sounds a woman makes in labor communicate important information about the woman's state of being and possible need for care.

Although the nature of a laboring woman's vocalizations is often understood by the experienced clinician and has been qualitatively described and categorized by experts in maternity care, the characteristic of parturients' vocalizations have not been quantitatively described and compared. Such objective differentiation offers several potential clinical benefits. First, if a woman's vocal utterances during labor could be shown to have different qualities that could be objectively and reliably differentiated, this information could be communicated and taught to practitioners or learners in a way that might facilitate their ability to recognize and respond to the needs of women during labor so that nursing care can be adjusted appropriately. Second, a systematic differentiation of these sounds would enable nursing educators to orient learners to the differential meaning of these sounds and thus accelerate their learning of relevant clinical cues that are often learned only through years of clinical experience. Third, if nonlinguistic features of spontaneous utterances by women in advanced labor can differentiate vocalizations reflecting stress-anxiety from those reflecting physical effort, these features would be excellent quantitative measures in future clinical research. They can contribute to the research designed to test the effects of various nursing interventions aimed to reduce stress-anxiety and to recognize the expulsive efforts heralding the second stage of labor.

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## Acoustics

Vocalizations are composed of combinations of simple sound waves. Each wave has a characteristic frequency and amplitude. Frequency is reported in cycles per second (Hz). Amplitude (the energy contained in the waveform) is measured in decibels (dB). The simple sound wave with the lowest frequency is the fundamental frequency (Fo) and is perceived as pitch. Variability in durations of adjacent Fo waves is termed jitter and is perceived as roughness (Table 1). Variability in amplitudes of adjacent Fo waves is termed shim-

**Table 1. Operational Definitions of Acoustic Measures**

1. Mean Fo: the arithmetic mean of the fundamental frequencies (pitch) of a voice sample, expressed in Hz.
2. Jitter: an average difference of contiguous Fo periods in milliseconds. Because jitter depends on the mean Fo or pitch, jitter is expressed as a percentage of Fo according to the formula:

$$\text{Jitter} = \frac{\text{Mean Difference of Adjacent Fo Periods}}{\text{Mean Fo Period}} \times 100$$

3. Shimmer: the mean differences in the amplitudes (energy) of adjacent Fo cycles, as measured by the formula:
   Shimmer = 20 × $\log_{10}$ (mean differences in the amplitudes of adjacent Fo cycles)
4. Ratio 1 (measure of tenseness): the ratio of the energy (in dB) in the higher versus the low spectral voice frequencies at 1000 Hz. The higher the value of Ratio 1, the greater the tenseness.

mer and is perceived as "brightness." A voice spectrum is a plot of the frequency and amplitude of all the simple waves in a vocalization. Tenseness indicates the relative amount of sound energy in the higher versus lower frequencies in the spectrum (Laver, 1980). For this study tenseness was measured as the ratio of sound energy above and below 1000 Hz (Ratio 1). Tense voices sound strident or metallic. Sensitive listeners can perceive larger variations in these acoustic properties. Laboratory analyses measure smaller variations.

### The Effects of Stress-Anxiety on Acoustic Measures

Scherer (1986) proposed that stress-anxiety (a) increases the tautness of laryngeal and vocal fold muscles, which increases Fo and also jitter and/or shimmer and (b) constricts the superior larynx and pharynx and tenses the remaining supraglottal airway muscles that together elevate the ratio of energy in the higher to lower voice frequencies, thereby increasing tenseness. Research findings, using 98 subjects and graduate oral comprehensive examinations as the stress-provoking situation (Fuller & Horii, 1989; Fuller, Horii, & Conner, 1992), supported the propositions in Scherer's theory concerning the effects of stress on tenseness and jitter but failed to support the proposition concerning Fo.

## METHODS

### Sample

The audio portion of videotapes from the expulsive phase of labor of a convenience sample of 10 women, aged 20 to 36 years, who had given informed consent for the videotaping of their labors were used for this analysis. These women were of low to moderate obstetric risk, afebrile, normotensive, having their first through fifth baby, and anticipating normal vaginal delivery. The videotapes were part of a research project studying the care of women during the second stage of labor (Roberts et al., 1989) and were recorded in four different birth settings. Four women had their babies in a tertiary hospital, three in a level II hospital with single room maternity "cluster units," one in an out-of-hospital birth center, and two at home. With the exception of one home birth tape recorded by a family member, all videos were videorecorded by research team members. Videotaping by the research team began when women experienced the urge to bear down or were judged by their care providers to be dilated 10 cm (completely dilated) and continued through the birth and first contact with their infants.

### Procedure

Videotapes were viewed by a graduate nurse-midwifery student who identified the work/effort, childlike, or out-of-control utterances, as described by McKay & Roberts (1990). The student had been previously oriented to this classification of the sounds by Drs. McKay and Roberts and also relied on her many years of obstetric nursing experience to differentiate the utterances. Three usable samples of each of the three types of utterances per subject were analyzed. A uniform segment from the middle of each utterance was digitized and filtered to remove sound below 70 Hz and above 9000 Hz and subsequently processed by computer software, which generated the acoustic measures used in this study.

### Measures

Accuracy of the audiotape recorder and signal-filtering apparatus were certified to be within established manufacturer's specifications. The accuracy and reproducibility of the digitizing hardware and software were excellent with an error rate of $<0.002\%$. The accuracy and reproducibility of the computer programs measuring acoustic variables were within (a) 0.5% for tenseness, (b) 1.0% for Fo, and (c) 5.0% for jitter and shimmer. Computer programs and further details of the programs are described elsewhere (Fuller, 1991; Horii, 1975, 1979; Horii & Hughes, 1972). Acoustic measures were generated from the digitized samples by valid

and reliable computer programs (Horii, 1974, 1979, 1980; Horii & Hughes, 1972).

Data were analyzed by repeated measures analysis of variance. This test compares the variation in one type of utterance among the subjects and also compares the variation among different types of utterances between and within subjects. The main difficulty in using repeated measures analysis of variance with a small sample size is that one may not be able to identify differences that might have actually been significant had a larger sample been used.

## FINDINGS

Results are presented in Table 2. The multivariate comparison was significant, Pillais' $F(1,9) = 4.33, p = .001$. This means that the test identified a significant difference for at least one acoustic measure between one or more of the three groups of utterance types. Work/effort utterances possessed more shimmer than did out-of-control utterances (Table 2). Univariate comparison indicated that (a) work/effort utterances contained more shimmer than the out-of-control utterances, (b) out-of-control and work/effort utterances were more tense (contained a higher Ratio 1) than were childlike utterances, (c) pitch (Fo) was higher in work/effort than in childlike utterances but did not differ between out-of-control and either childlike or work/effort utterances, and (d) jitter did not differ among the three types of utterances. Thus, the three types of utterances can be acoustically differentiated as follows. Out-of-control utterances are more tense than childlike utterances, but their levels of shimmer and pitch are similar. Work/effort utterances are more tense, contain more shimmer, and are higher pitched than are childlike utterances. Work/effort utterances contain more shimmer than out-of-control utterances, but their levels of tenseness and pitch are similar.

The greater pitch in work/effort than in childlike utterances agrees with the findings reported by McKay and Roberts (1990); the lack of difference in pitch between work/effort and out-of-control utterances does not. The higher pitched sounds that the caregivers (nurses and midwives) reported they used to differentiate between out-of-control and work/effort utterances in the McKay and Roberts study (1990) may actually reflect differences in tenseness. The acoustically untrained listener often perceives a more tense utterance as being higher in pitch (Y. Horii, personal communication, 1989). The lack of significant differences in jitter among the three types of utterances in this study is inconsistent with earlier studies (Fuller & Horii, 1989; Fuller et al., 1992) that indicated that jitter increased in stressful situations. The reason may be that only less precise measures of jitter can be obtained when voice samples are collected using the microphone of a videocamera, whereas the earlier studies obtained more precise, less variable measures of jitter by taping a special device to the subject's throat.

The purpose of the acoustical analysis of the utterances made by women in advanced labor was to determine if the classification of the sounds by experienced clinicians had quantitatively different acoustical properties. Such differences would support the clinical discrimination among states of distress versus verbalizations of effort that are used by clinicians to interpret labor progress and women's needs. The significant differences in acoustic measures among the three types of utterances indicate that these measures do differentiate among them.

**Table 2. Mean Acoustic Measures and Univariate Results of Repeated Measures Analysis of Variance[a]**

| | Mean Acoustic Value per Type of Utterance | | | Univariate *F* Values for Comparisons[b] | | |
|---|---|---|---|---|---|---|
| Measures | OOC | W/E | C | OOC versus C | OOC versus W/E | C versus W/E |
| Mean Fo (Hz) | 503 | 590 | 406 | 3.12 | 1.79 | 10.84[c] |
| Jitter (%Fo) | 1.68 | 2.18 | 1.67 | 0.01 | 2.72 | 3.29 |
| Shimmer (dB) | 0.68 | 1.02 | 0.89 | 1.31 | 6.62[c] | 2.01 |
| Tenseness (Ratio 1) | 2.01 | 1.78 | 1.23 | 7.26[c] | 2.65 | 6.27[c] |

Abbreviations: OOC, out of control; C, childlike; W/E, work/effort.

[a] Multivariate $F = 4.33, p = .05$.

[b] $df = 1, 9$.

[c] $p < .01$.

Differences in tenseness differentiate childlike utterances from work/effort or out-of-control utterances. Differences in shimmer differentiate sounds suggesting out-of-control from those of work/effort. Thus, for example, a sound suggesting a need for help (out of control) can be objectively differentiated from a vocal expression of work/effort.

The results of this analysis indicate that sounds or utterances by women have significantly different measurable acoustical qualities that can be related to different meanings or clinical needs as distinguished by nurses and midwives. These results, therefore, provide measurable, empirical validation of the discrimination among sounds that has been reported by clinicians who care for women during childbirth. This acoustical discrimination supports the potentially physiological differences among these sounds that have implications for their clinical interpretation and the identification of the needs of women in advanced labor. There is validation for the nurse or nurse-midwife who recognizes the sound of work/effort and decides to defer a vaginal examination until there is a more compelling reason to re-evaluate labor progress by a vaginal examination. Likewise, there is validation for the recognition of a sound that signifies a "need for help" (Wiedenbach, 1974) because the quality of the voice that is out of control is different from work/effort and merits the nurse's or midwife's immediate attention. Thus, there may be (a) merit in teaching learners and clinicians to recognize the different qualities (e.g., pitch, shimmer, and tenseness) in the sounds they hear in this clinical context and (b) a reason to advocate for not "keeping quiet" by women when they are in labor because the utterances of these women may reveal their needs for further nursing assessment or assistance. Additionally, encouraging the woman to engage in healthy vocalizations may assist her in coping with labor, just as making sounds can help anyone deal with stressful life situations.

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