Effects of Marijuana Use during Pregnancy on Newborn Cry

Barry M. Lester
Brown University and Emma Pendleton Bradley Hospital
and Women and Infants’ Hospital

Melanie Dreher
University of Miami

LESTER, BARRY M., and DREHER, MELANIE. Effects of Marijuana Use during Pregnancy on Newborn Cry. CHILD DEVELOPMENT, 1989, 60, 765–771. The effects of maternal marijuana use on the newborn cry were studied in Jamaica, where it was possible to rule out confounding factors such as the use of other substances and demographic variables that have clouded previous studies and where higher dosages may make the effects more visible. The acoustic characteristics of the cries of 20 infants of marijuana users and 20 controls were analyzed. The cries of the infants of marijuana users were shorter, had a higher percentage of dysphonation, a higher and more variable fundamental frequency, and a lower first formant than controls. There was also a dose response relation between the first formant and marijuana use. We suggest that heavy marijuana use affects the neurophysiological integrity of the infant.

Clinical studies have reported detrimental effects of marijuana use during pregnancy on fetal development and neonatal behavior (Fried, 1982; Fried, Watkinson, & Dillon, 1987; Gibson, Baghurst, & Colley, 1983; Greenland, Staisch, Brown, & Gross, 1982; Hingson et al., 1982; Linn et al., 1983). Marijuana use during pregnancy is associated with a variety of adverse outcomes, including prematurity, low birthweight, decreased maternal weight gain, complications of pregnancy, difficult labor, congenital abnormalities, increased stillbirth and perinatal mortality, perinatal problems, and poor Brazelton scale scores (Fried, 1982; Fried et al., 1987; Gibson et al., 1983; Greenland et al., 1982; Hingson et al., 1982). However, perhaps because of methodological problems, the studies are inconsistent, showing one or the other adverse outcome.

In these studies, it has been difficult to control for possible confounding factors that could contribute to adverse fetal outcome, such as the use of alcohol, tobacco and/or other recreational drugs, and socioeconomic variables. Marijuana use and sociodemographic variables such as lower income and education, minority status, and poor prenatal care are interrelated, and assessment of an independent effect has been difficult to demonstrate (Hingson et al., 1982; Linn et al., 1983). A related problem has to do with the identification of users and nonusers (Hingson et al., 1986). Because it is an illegal substance, the reliability of self-report of marijuana and other illicit drug use is difficult to establish.

The present study was conducted in Jamaica to address some of the methodological problems of previous work. In our sample, the use of marijuana was not confounded with the use of other drugs, alcohol, or tobacco smoking. Socioeconomic factors were also controlled, with both users and nonusers drawn from the lower socioeconomic sectors of the country. The reliability of marijuana usage was increased by complementing formal interviews with direct observation and long-term monitoring of women in their homes and workplaces.

Also, because of the frequency and amount of usage and the higher concentration of the major psychoactive ingredient, delta-9-tetrahydrocannabinol (THC), Jamaica provides the opportunity to study stronger effects than might be observed in the United States. These effects should be easier to measure so that we can begin to isolate specific effects of marijuana use during pregnancy on neonatal outcome.

This work was supported in part by a grant from the March of Dimes to the second author. Send reprint requests to Barry M. Lester, Division of Child and Adolescent Psychiatry, Bradley Hospital, 1011 Veterans Memorial Hospital, East Providence, RI 02915.

[Child Development, 1989, 60, 765–771. © 1989 by the Society for Research in Child Development, Inc. All rights reserved. 0009-3920/89/6004-0021$01.00]
Our primary interest was in relating maternal marijuana use to the acoustic characteristics of the infant's cry. Research since the 1960s has identified acoustic characteristics of the infant cry that correlate with medical abnormalities, including cri du chat, Down syndrome, hyperbilirubinemia, encephalitis, meningitis, asphyxia, and various forms of brain damage (Karellitz & Fischelli, 1962; Lind, Vuorenskoski, Rosenberg, Partanen, & Wasz-Hockert, 1970; Lind, Wasz-Hockert, & Vuorenskoski, 1965; Ostwald, Phibbs, & Fox, 1968; Vuorenskoski et al., 1966; Wasz-Hockert, Lind, Vuorenskoski, Partanen, & Valanne, 1968) and with factors that place the infant at risk for later handicap. These include prematurity, low birthweight, undernutrition, and obstetrical complications (Lester, 1976, 1984, 1987; Lester & Zeskind, 1979; Michelsson, Sirvio, & Wasz-Hockert, 1977; Tenold et al., 1974; Zeskind & Lester, 1978). More recently, acoustic cry characteristics of the cry measured during the neonatal period in term and preterm infants were related to Bayley scale scores at 18 months and McCarthy scores at 5 years (Lester, 1987). The cry is thought to reflect the neurophysiological integrity of the infant and may be useful in the early detection of the infant at risk for adverse developmental outcome.

The notion that the cry is related to the neurophysiological status of the infant is based on human and animal studies that led to the development of conceptual models that describe the anatomical and physiological basis for the production and neurologic control of the cry. In particular, the neurological integrity of the infant has been related to the stability of laryngeal coordination and vocal tract mobility (Bosma, Truby, & Lind, 1965; Golub & Corwin, 1984; Lester, 1984, 1987). Brainstem activity as mediated by the cranial nerves determines sound qualities of the cry, including the fundamental frequency (perceived pitch) and the formants or resonance frequencies. The acoustically important muscles of the larynx, pharynx, neck, and chest are controlled by the vagal complex; cranial nerves IX (glossopharyngeal), X (vagal), XI (accessory), and XII (hypoglossal); and by the phrenic and thoracic nerves. Damage to any of these nerves or their nuclei will affect directly the acoustic characteristics of the cry. For example, if the nucleus of the vagus, the tenth cranial nerve, is damaged, this would alter neural input to the thyroarytenoid, including the vocalis, cricothyroid, and the cricoarytenoid muscles of the larynx. These muscles determine the tension of the vocal folds, which affects the fundamental frequency of the cry. Similarly, neural input to the vocal tract affects the contour and cross-sectional area of the supraglottal airway, which determine the formant frequencies of the cry. In recent studies (Rapisardi, Vohr, Cashore, Peucker, & Lester, 1989; Vohr, Lester, Peucker, Oh, & Cashore, 1989), the brain auditory evoked response was related to acoustic cry characteristics, supporting the notion that the cry is mediated by brain-stem activity.

In the drug literature, high-pitched cries have been documented in infants of narcotic addicted mothers (Blinick, Tavolga, & Antopol, 1971) and were anecdotally reported in a study of infants of marijuana users (Fried, 1982). We hypothesized that acoustic characteristics of the cry that have been used to reflect the neurophysiological integrity of the infant would correlate with maternal marijuana use during pregnancy.

Method

The women and the setting.—Pregnant women were recruited from three rural communities in Jamaica. The communities were selected based on their representativeness and the presence of rural working-class women, a prenatal clinic, and a marijuana- or ganja-using population. One of the communities is the site of the Ethiopian Zion Coptic Church, a Rastafarian sect that endorses the smoking of ganja as the primary sacrament.

The pregnant women were interviewed as part of a larger ethnographic medical anthropological study of marijuana use in these communities. For the present study, 20 marijuana users and 20 nonusers were followed through the birth of their infants. Our primary interest was in the analysis of the acoustic characteristics of the infants' cries.

Marijuana consumption was determined by formal interview and by direct observation of the women in their communities during social activities, and confirmed by key informants in the communities. From the interview, the frequency and quantity of marijuana consumption were determined by trimester as well as overall. Marijuana was consumed both by smoking what are referred to as "cigars" and by brewing marijuana tea. The cigars contain approximately five times the quantity of marijuana as the marijuana cigarette common in the United States. In addition, the concentration of THC per gram in Jamaican marijuana is three to four times higher than that of domestic marijuana (Edmonson, 1985). When marijuana is smoked,
50% of the THC is absorbed into the bloodstream, in contrast to 5%-10% absorption through oral ingestion (Nahas, 1979). Our estimates of marijuana use included the frequency and quantity of both cigars and tea.

The two groups of mothers, 20 users and 20 nonusers, were from lower socioeconomic families as determined by income and occupation. The two groups were also similar in terms of age (15-35 for smokers, 16-37 for nonsmokers), gravida (1-7 for smokers, 1-8 for nonsmokers), and parity (1-6 for smokers, 0-8 for nonsmokers) and in the use of other drugs, alcohol, or tobacco, which was reported as rare or occasional. This was also confirmed by direct observation.

The nonusers reported that they did not smoke marijuana cigars or drink marijuana tea during pregnancy. They felt that marijuana may be harmful to their infants, based on warnings from the “old people” about babies born “viled up” with “black mouths,” “mashed up brains,” and “cracked skin.”

All of the women in the user group smoked marijuana cigars from the first trimester, and 15 smoked during all three trimesters. The reported frequency of smoking marijuana in this group ranged from 1-10 cigars per day \( (M = 4.15) \) and 2-71 per week \( (M = 18.68) \). Marijuana tea was consumed by 16 of the mothers starting in the first trimester. Marijuana smoking to the fetus. However, the women who smoke have been given marijuana use during pregnancy in this sample is substantially higher than in U.S. studies (Fried, 1982; Gibson et al., 1983; Greenland et al., 1982; Hingson et al., 1982; Linn et al., 1983).

The interviews showed that many of the users were aware of the potential harm of marijuana smoking to the fetus. However, they reported that smoking controlled first trimester nausea and vomiting, reduced fatigue, and helped them sleep better and relax. The influence of the Rastafarian sect has also increased the social status of marijuana smoking. Women who smoke have been given the title “roots daughter,” which signifies a woman who has “good brains” and who can smoke “hard as a man.”

**Characteristics of the infants.**—The infants were all born in hospital at term (gestational age ranged from 38 to 42 weeks). Birthweights averaged 3,096 grams in the group of infants of nonsmokers (range, 2,455-3,830 grams) and 3,206 grams in the group of infants of smokers (range, 2,367-3,901 grams). There was one low-birthweight infant (<2,500 grams) in each group. Apgar scores were reported as >7 for all infants, although the reliability of these scores was questionable. All of the infants were judged to be healthy. None were sent to the special care nursery, and no abnormalities were noted.

**Cry recording and analysis.**—The cry was recorded and analyzed using previously established procedures (Lester, 1987). The cry was tape-recorded at home on the fourth or fifth day after birth. The infant was placed in a supine position with the microphone held 15 cm from the infant’s mouth. Standard newborn reflexes were used to elicit the cry. The first 10 sec of the cry were used for acoustic analysis. The cry was analyzed using a computer-extraction system developed in collaboration with Physiologic Diagnostic Service (PDS, Inc.; Cambridge, MA). The cry is filtered at 5 Hz and digitized at 10 kHz. The Fast Fourier Transform is used to compute the log magnitude spectrum for each 25-msec block of the cry. Summary variables are computed across the 25-msec blocks. The following summary variables were used for the present study:

**Duration:** Average amount of time (sec) of each cry phonation that occurs during the expiratory phase of respiration.

**Percent dysphonation:** Proportion of the cry blocks in which the signal is inharmonic. This is a measure of the amount of turbulence or “noise” in the cry.

**Fundamental frequency (f0):** Frequency of vocal fold vibration; it is what we hear as voice pitch. Both the median and the range of f0 were computed. F0 is determined by subglottal pressure and by vocal fold tension from the intrinsic muscles of the larynx.

**First formant (F1):** The formants are the resonance frequencies that occur as a result of the filtering by the vocal tract. F1 is determined by the contour and cross-sectional area of the supraglottal airway. Both the median F1 and the range of F1 were computed.

**Results**

The means and standard deviations of the six acoustic cry variables for the smokers and nonsmokers are shown in Table 1. The cry characteristics of the smokers and nonsmokers were compared by multivariate analysis of variance (MANOVA) of the six dependent cry variables. The MANOVA was statistically significant, \( F(6) = 11.78, p < .001 \), with significant univariate effects observed for five of the six cry variables. The cries of the infants of
mothers who smoked marijuana were shorter in duration, $F(1,38) = 6.02, p < .02$, and had a higher percentage of dysphonia, $F(1,38) = 16.10, p < .003$, a higher median $f_0$, $F(1,38) = 5.07, p < .03$, a wider range of $f_0$, $F(1,38) = 24.02, p < .0001$, and a lower median $F_1$, $F(1,38) = 16.10, p < .0003$, than the cries of the infants of non-smokers. The median correlation among the six acoustic variables was $r = .15$ (range, $r = .003$ to -.35).

To determine possible dose-response relations, Pearson correlation coefficients were computed between the cry variables and the number of cigars per week and the number of cigars per day. Significant correlations were found for the cry measure of median $F_1$ (Fig. 1). The frequency of marijuana smoking was inversely correlated with the median $F_1$ of the cry. As shown in Figure 1, a lower $F_1$ in the cry was related to more marijuana smoking per day, $r = - .58, p < .01$. A lower $F_1$ was also related to more marijuana smoking per week, $r = - .52, p < .02$. There was no relation between marijuana tea ingestion (number of cups per day or week) and the cry measures.

**Discussion**

Marijuana smoking during pregnancy in Jamaica appears to affect the acoustic characteristics of the newborn cry. In other studies, these acoustic characteristics have been related to perinatal risk factors and to later developmental outcome (Lester, 1987; Lester & Boukydis, 1985). The lower average first formant ($1,114$ vs. $1,454$ Hz) in the infants of marijuana smokers is noteworthy because it is almost a full standard deviation lower than what we find in normal infants in the United States using the same methods of cry recording and analysis. For example, in unpublished data from a normative sample of over $1,200$ infants, the average $F_1$ is $1,393$ Hz (SD = 311). The $F_1$ measure also suggested a dose-response relation. Mothers who smoked more marijuana during pregnancy had infants with lower first formant cries. $F_1$ can be low for anatomical reasons that relate to the con-

![Graph](image-url)

**Fig. 1.—Correlation between average first formant of cry and number of marijuana cigars per day**
configuration of the vocal tract or due to motor innervation of the supraglottal airway that reflects neural control. This could indicate respiratory involvement. Linn et al. (1983) reported a higher rate of malformations of the respiratory tract in infants of marijuana users, although other confounding variables may have been involved. Our other findings of increased dysphonation or turbulence and shorter cry durations related to marijuana use could also suggest respiratory involvement.

We also found a higher fundamental frequency (f0) and a wider range in f0 related to maternal marijuana use. Clinically, we would hear this as a higher-pitched and more variable cry. In a previous study, although the cry was not recorded, Fried (1982) reported that one-third of the infants of marijuana smokers and none of the controls had high-pitched cries.

Neural mediation through the ninth, tenth, eleventh, and twelfth cranial nerves and the thoracic and phrenic nerves plays a large role in the control of the cry, including f0 and the formants (Lester, 1987). The role of the brain stem appears to be in the mechanics of cry production. Higher centers are involved in the configuration and triggering of the specific vocal pattern. The distress call in monkeys is mediated by the limbic system (MacLean & Newman, 1987), which includes the hypothalamus, important in the control of emotions such as crying. Buchwald and associates recently showed that in cats, electrical stimulation of the hypothalamus produces distress calls similar to the spontaneous calls of the same animal (Altafullah, Shipley, & Buchwald, 1987). In other animal studies, THC has been found to cause changes in the limbic system in monkeys (McIsaac, Fritchie, Idanpaan-Heikkila, Ho, & Englert, 1971) and in rats (Landfield, Cadwallader, & Vinsant, 1987). It is possible that some of the effects on the cry observed in the present study were due to direct effects of THC on brain stem or higher regions.

It is important to interpret these effects in light of the amount of marijuana ingested by these mothers. Considering the concentration of THC (three to four times stronger than in the United States) and the amount of marijuana in a typical Jamaican "cigar" (five times as much as the United States), even at the same frequency of marijuana use as in the United States, these Jamaican women were probably exposed to 15-20 times as much marijuana as women that have been studied in the United States.

Also, compared to studies conducted in the United States, we were better able to control for demographic factors and the use of other substances. We were also able to obtain a more reliable estimate of marijuana use because of its cultural acceptance in Jamaica, which also made it possible to include several validity checks on maternal self-report.

Acoustic characteristics of the cry have been used as a measure of the neurophysiological status of the infant. Our findings provide evidence that maternal marijuana smoking during pregnancy presents a toxic threat to the biological integrity of the infant. It has been suggested that marijuana could be classified among the psychotropic drugs that act as "behavioral teratogens" (Nahas, 1979). We usually think of teratogens as agents that cause physical malformations, such as thalidomide, or more recently the fetal alcohol syndrome (Jones, Smith, Ulleland, & Streissguth, 1973). However, some agents have been found to have functional sequelae, such as growth retardation and behavioral deficits, in the absence of physical malformations (Hutchings, 1983). Behavioral teratology refers to research dealing with these functional effects, as, for example, in the case of the neonatal withdrawal syndrome in infants of narcotic addicted mothers (Finnigen, 1981). The high-pitched cry has already been identified as part of this syndrome (Blinick et al., 1971). Fried et al. (1987) found that prenatal marijuana exposure was associated with symptoms similar to mild narcotic withdrawal. Our findings extend the effects on the cry to maternal marijuana use and support the classification of marijuana as a behavioral teratogen.

Agents taken during pregnancy can affect infant functioning because of direct effects on the central nervous system or indirectly as altered behavior affects the developing parent-infant relationship. In previous work, the cry has been described as a biosocial phenomenon (Lester, 1984); biological effects refer to the cry as a measure of CNS integrity. Social effects refer to the effects of cry characteristics on how parents perceive the infant, which affects parenting behavior. In the context of the current study, it is likely that the significance of the acoustic characteristics of the cry for infant functioning and development may lie in its biosocial significance. As a measure of the neurophysiological integrity of the infant, the cry reflects the direct effects of marijuana on the CNS and may predict later developmental outcome. Indirect effects of marijuana are mediated by the effects of cry characteristics on the developing parent-infant relation-
ship, which can also affect developmental outcome.

References


