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The Effects of Hydrotherapy on Anxiety, Pain, Neuroendocrine Responses, and Contraction Dynamics During Labor

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Abstract

Background—Hydrotherapy (immersion, or bathing) is used worldwide to promote relaxation and decrease parturient anxiety and pain in labor, but the psychophysiological effects of this intervention remain obscure.

Design—A pre-test post-test design with repeated measures was used to examine the effects of hydrotherapy on maternal anxiety and pain, neuroendocrine responses, plasma volume shift and uterine contractions during labor. Correlations among variables were examined at three time points (pre-immersion and twice during hydrotherapy).

Methods—Eleven term women (mean age 24.5 years) in spontaneous labor were immersed to the xiphoid in 37°C water for 1 hr. Blood samples and measures of anxiety and pain were obtained under dry baseline conditions and repeated at 15 and 45 min of hydrotherapy. Uterine contractions were monitored telemetrically.

Results—Hydrotherapy was associated with decreases in anxiety, vasopressin and oxytocin levels at 15 and 45 min (all $p < .05$). There were no significant differences between pre-immersion and immersion pain or cortisol levels. Pain decreased more for women with high baseline pain

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The study was conducted at East Carolina University.

than for women with low baseline levels at 15 and 45 min. Cortisol levels decreased twice as much at 15 min of hydrotherapy for women with high baseline pain as for those with low baseline pain. Beta-endorphin levels increased at 15 min but did not differ between baseline and 45 min. During immersion, uterine-contraction frequency decreased. A positive plasma volume shift at 15 min was correlated with contraction duration.

Conclusions—Hydrotherapy during labor affects neuroendocrine responses that modify psychophysiological processes.

Keywords

Hydrotherapy; Labor; Anxiety; Pain; Neuroendocrine Responses

Hydrotherapy (immersion or bathing) is used worldwide by thousands of women to promote relaxation and decrease parturient anxiety and pain during labor (Alderdice et al., 1995; Benfield, 2002; Benfield, Herman, Katz, Wilson, & Davis, 2001; Cammu, Classen, Van Wettere, & Derde, 1994; da Silva, de Oliveira, & Nobre, 2009; Eldor, Burstein, Dudakova, & Stark, 1992; Lenstrup et al., 1987; Rosenthal, 1991). Hydrotherapy is even thought to correct uterine dystocia (slow labor; Cluett, Pickering, Getliffe, & St George Saunders, 2004). For parturients without complications, with intact or ruptured membranes, hydrotherapy is not associated with risk of infection for mother or neonate (Benfield et al., 2001; Busine & Guerin, 1987; Cammu et al., 1994; Eriksson, Ladfors, Mattsson, & Fall, 1996; Lenstrup et al., 1987; Mesrogli, Goeschen, Siefert, Pohl, & Schneider, 1987; Robertson, Huang, Croughan-Minihane, & Kilpatrick, 1998; Rosenthal, 1991; Rush et al., 1996; Waldenstrom & Nilsson, 1992). It is unclear, however, whether hydrotherapy affects labor and delivery outcome variables such as analgesia use and length of labor. (For a comprehensive review of the research on hydrotherapy in labor, see Benfield, 2002).

Women using hydrotherapy report feeling relaxed and comforted by the warm water (Maude & Foureur, 2007), and relaxation may be associated with the primary physiological effect of immersion, an increase in central blood volume (Farhi & Linnarsson, 1977; Hammerum et al., 1998; Johansen, Pump, Warberg, Christensen, & Norsk, 1998; Risch, Koubenec, Beckmann, Lange, & Gauer, 1978; Risch, Koubenec, Gauer, & Lange, 1978). It is well established that as water depth increases, hydrostatic pressure increases, involving a larger number of veins and producing a greater return of blood volume to the heart (Risch, Koubenec, Beckmann, et al., 1978). Stroke volume also increases, resulting in greater cardiac output (Risch, Koubenec, Beckmann, et al., 1978; Risch, Koubenec, Gauer, et al., 1978; Sheldahl et al., 1987) and a concomitant reduction in heart rate due to the stretching of baroreceptors whose firing rate is increased (Farhi & Linnarsson, 1977; Risch, Koubenec, Gauer, et al., 1978).

Immersion is also associated with decreases in neuroendocrine responses (e.g., levels of cortisol and catecholamines) in healthy adults. At a thermoneutral temperature of 34.5 °C, at differing depths, during both rest and exercise, immersion of men (mean age 23.5 years) has been associated with decreases in levels of plasma norepinephrine (Grossman, Goldstein, Hoffman, Wacks, & Epstein, 1992; Johansen et al., 1998; Norsk, Bonde-Petersen, & Christensen, 1990), epinephrine (Connelly et al., 1990; Grossman et al., 1992), beta-endorphin, and cortisol (32°C) (Sramek, Simeckova, Jansky, Savlikova, & Vybiral, 2000). In addition immersion was also associated with rapid vasopressin suppression secondary to decreased blood osmolality (Hammerum et al., 1998). Thus, based on data from healthy men, immersion in a thermoneutral condition can be viewed as stress reducing.

Elevations in stress hormones associated with anxiety and pain have been linked with ineffective uterine contractility in both animals and humans. In a classic study, the

introduction of environmental stress caused significant increases in labor inertia in mice (Newton, Peeler, & Newton, 1968). In pregnant rats, exogenously administered epinephrine and norepinephrine reduced uterine contractility by at least one-third (Segal, Csavoy, & Datta, 1998). Constriction of the uterine and placental blood vessels at elevated levels of epinephrine and norepinephrine has also been demonstrated in stressed sheep (Marcus, Vertommen, Van Aken, & Wouters, 1996; Rosenfeld & West, 1977; Shnider et al., 1979). Rat and pig models have suggested that endogenous opioid release may be responsible for prolonged labor through oxytocin inhibition secondary to acute stress (Douglas & Russell, 2001; Lawrence et al., 1992; Leng et al., 1988). Limited evidence, however, exists on these relationships in humans.

In women, anxiety and pain are associated with slowed labor, higher levels of stress hormones, and greater use of oxytocin and labor analgesia (Alehagen, Wijma, Lundberg, & Wijma, 2005; Alexander, Sharma, McIntire, Wiley, & Leveno, 2001; Anim-Somuah, Smyth, & Howell, 2005; Burns, 1976; Garcia & Garcia, 1955; Henry & Nand, 2004; Lederman, Lederman, Work, & McCann, 1985; Lederman, Lederman, Work, & McCann, 1978; Newton, Schroeder, Knape, & Bennett, 1995; Panni & Segal, 2003; Waldenstrom & Irestedt, 2006). With increasing plasma levels of epinephrine, uterine activity decreases. With higher levels of norepinephrine, incoordinate uterine activity increases (Zuspan, Cibils, & Pose, 1962).

No study, however, has directly evaluated the effects of hydrotherapy on maternal anxiety and pain in labor using measures of neuroendocrine response and uterine contractility. In our study, therefore, we assessed the effects of hydrotherapy on anxiety and pain (using visual analogue scales for anxiety [VASA] and pain [VASP]), stress-related hormones (epinephrine [E], norepinephrine [NE], cortisol [C], beta-endorphin [βE], oxytocin [O], and vasopressin [V]), plasma volume shift (PVS%; using hemoglobin [HGB] and hematocrit [HCT]), and uterine contractions (CX), in healthy, term parturients in early active labor. We hypothesized that hydrotherapy would 1) reduce maternal anxiety and pain in labor, 2) reduce levels of neuroendocrine hormones more effectively for women with high pain than for those with low pain, and 3) increase uterine contraction frequency and duration related to plasma volume increase.

Methods

Study Design and Sample

In this pilot study, we used a pre-test–post-test design with repeated measures. Women were their own controls, offsetting the large individual variation occurring in stress hormone production and allowing for a smaller sample.

We recruited participants from the low-risk obstetrical clinics at the County Health Department and the university's School of Medicine and from two private obstetrical practices. The university Institutional Review Board approved the study. Antepartal inclusion criteria were age of 17 through 40 years; a singleton pregnancy; low risk for obstetrical complications; nonsmoking, a hematocrit ≥ 32%; no history or current diagnosis of drug or physical abuse, genital herpes, depression, anxiety or severe psychosocial problems; and no previous surgical delivery or labor less than 1 hr in length. Women who met these study criteria at 37 weeks' gestation were invited to participate.

Over a 14-month time period, we reviewed approximately 1015 charts to identify 135 women who met the inclusion criteria. These women were approached about participation during a scheduled prenatal visit, and 41 of the 135 consented. Refusal to have blood drawn was the primary reason for not giving consent followed by the desire for epidural analgesia

in labor. Women in active labor (cervical dilatation range 3–6 cm) at 37 to 41 weeks' gestation were admitted to a private room in the labor unit of a regional medical center. A negative Contraction Stress Test, intact or spontaneously ruptured membranes with clear fluid (< 6 hr), vital signs within normal limits for early labor, ≤ small urinary ketones and no caffeine within the previous 4 hr were additional criteria for study participation. Of the 41 women who had consented to participate, 30 were excluded for intrapartum factors such as precipitous or advanced labor, meconium in the fluid, late decelerations, breech presentation, pre-eclampsia, induction, pitocin augmentation with fluid bolus, epidural request and lack of a room with a tub adaptor. These intrapartum factors led to approximately 73% attrition in this group of healthy women. We had anticipated up to a 50% attrition rate between consent and labor admission based on our previous research and clinical experience. Late pregnancy is a very dynamic time, often resulting in acute maternal/fetal changes necessitating intervention. Participants completing the study received a $100.00 cash voucher redeemable at the School of Medicine cashier's office.

Procedures

On admission of participants to the delivery unit, an indwelling catheter was placed in their antecubital vein, which were heparinized (5 U/1.5ml) to maintain patency and then covered with a waterproof occlusive dressing. Fetal heart rate and uterine contractions were continuously monitored by external telemetry (Corometrics Maternal Fetal Monitor 128 and Telemetry System 340). A portable pool (Aqua Eez 145 gal) was brought into the room, connected and partially filled with warm tap water. Women reclined in bed at a 45° angle for 30 min. Blood samples were drawn under dry baseline conditions. Women were then helped into the tub, which we continued to fill to within 11–12 cm of the upper rim; they reclined at a 45° angle until they were immersed to the xiphoid in 37°C water for 1 hr. Water temperature was checked every 15 min and adjusted as necessary.

Before each blood draw, vertical VASA and VASP were administered. Perception of anxiety was measured using a VAS consisting of a 100-mm vertical line anchored at the bottom with "no anxiety" and at the top with "maximum anxiety," with possible scores ranging from 0 to 100. A separate scale with the same format was used to measure pain. The reliability, validity and method of analysis have been previously described (Benfield, Herman, Katz, Wilson & Davis, 2001).

Blood samples were obtained under dry baseline conditions and repeated at 15 and 45 min of hydrotherapy. Vacutainers containing EDTA were used to collect blood for stress hormone analysis. Trasylol 5000KIU was added to each sample reserved for βE analysis to inhibit proteolysis. All samples were placed on ice and, at the conclusion of data collection for each participant, spun at 3000 rpm for 15 min at 4°C. The plasma was aspirated and stored at −80°C for later analysis. Samples for HGB and HCT remained at room temperature and were analyzed immediately following data collection for each participant.

No adjustment for hormone levels was made because, according to immersion expert Peter Norsk (personal communication, 8-3, 06), "The increase in plasma volume was caused by the shift in Starling equilibrium in the peripheral, submersed tissues. Fluid from the interstitial space entered the intravascular space, causing the plasma volume expansion; because the substances measured were evenly distributed in the whole extracelluar space (intravascular + interstitial) the concentrations in the two spaces were presumably the same."

CX frequency was taken from the hard copy of the monitor strip by counting the CX then standardizing into 10-min units following this formula: number of CX/min of time measured x 10 min. All CX measured under dry conditions were compared with all CX measured under wet conditions. Only CX that were clearly identifiable were counted. The same CX

used for frequency were measured for duration with calipers. Frequency and duration analysis was triple checked for accuracy on 2 separate days by the same examiner.

The data and safety monitoring plan required the primary author (RDB), a nurse-midwife, and the senior obstetrician (ERN) to review all data collected after every two participants completed the study.

Assays

All samples remained frozen until they end of the study when assays were run using the following techniques.

Plasma E and NE were analyzed using HPLC Chromsystems System and Kit (Specialty Laboratory, Valencia, CA, CLIA number 05D0550302). For E, the lower sensitivity was < 10 pg/ml; intra-assay coefficient of variation (CV) C1 = 14%, C2 = 8.3%; inter-assay CV C1 = 18.7%, C2 = 16.7%. For NE, the lower sensitivity was < 10 pg/ml; intra-assay CV C1 = 9.8%, C2 = 8%; and inter-assay CV C1 = 10.6%, C2 = 9.8%. Only one sample drawn at 15 min into the bathing intervention fell below assay sensitivity.

Plasma C was analyzed using a chemiluminescent immunoassay system (Access Immunoassay System, Beckman Coulter, Fullerton, CA). Sensitivity ranged from 0.4 to 60.0 μg/Dl; intra-assay CV% was ~8% @ 6 ug/Dl and less at higher concentrations, with an average SD error of duplicates of 2.71%. Samples were diluted 4 times with diluent A (0.5% ProClin 300) to fall within the detectable limits of the assay.

Plasma O was extracted using the C18 Sep-COLUMN then analyzed using EIA from Assay Designs, Inc. (Ann Arbor, MI). Sensitivity was 11.7 pg/ml and ranged from 15.6 to 1000 pg/ml; intra-assay CV was 4.18% and inter-assay CV 4.21%, with an average SD error of duplicates of .88%. V was analyzed using RIA from Alpco Diagnostics (Windham, NH). Sensitivity was 1.25 pg/ml and ranged from 1.25 to 80 pg/ml; intra-assay CV was 6%, and inter-assay CV was 9.9%, with an average SD error of duplicates of 4.47%.

βE was extracted using C18 Sep-COLUMN then analyzed using EIA from MD Biosciences (St. Paul, MN). Sensitivity was .12 ng/ml and ranged from 0.1 to 100 ng/ml; intra-assay CV was 4.4%, and the average SD error of duplicates was 3%.

HGB and HCT were analyzed by the hospital Hematology Laboratory, Abott Cell Dyn Model 4000, using a standard range of commercial controls run daily and random normal patient values, including low, normal and high values run in blind duplicate before each shift to counteract any instrument drift. Dill and Costill's (1974) formula was used to calculate plasma volume percentage change, using HGB and HTC as indirect measures of uteroplacental perfusion. Hemoglobin concentration was used as a correction factor because its level remains constant when intravascular shifts occur with water immersion. This method has been validated for use with immersed pregnant women and women in labor (Benfield et al., 2001; Katz, McMurray, Berry, & Cefalo, 1988).

Statistical Analysis

Changes in pain, anxiety, stress hormone levels, and contraction frequency and duration from dry to 15 and 45 min of water immersion were assessed with the Wilcoxon signed rank test. Baseline pain scores spontaneously clustered into two distinct groups, women with low (≤ 50 mm) and high pain (≥ 70 mm) with no scores falling between these values. Levels of stress hormones and anxiety were compared between the low- and high-pain groups using the Mann-Whitney U Test. Correlations were assessed using the Spearman's correlation. Statistical significance was set at $p < .05$; p values were not adjusted for multiple testing.

Results

Table 1 shows the demographic characteristics for the 11 healthy women who completed the study. The mean cervical dilation for participants on admission was 4 cm. Labor duration ranged from 126 to 1294 min. No participant had analgesia during the study period, and no maternal or fetal infections or abnormal fetal heart rates were attributed to hydrotherapy. Of the 11 participants, 1 nulliparous woman received no analgesia and delivered within minutes after leaving the tub, 9 women received IV analgesia at approximately 10, 15, 17, 30, 60, 90, 120, 270, and 480 min after leaving the tub; 5 women subsequently received pitocin augmentation or epidural analgesia, and 4 received both; 9 women experienced spontaneous vaginal delivery and 2 had cesarean sections for failure to progress with cephalopelvic disproportion. Neonatal mean APGAR scores were 7.8 (range 6–9) at 1 min and 9 (range 9–10) at 5 min.

When compared with pre-immersion levels (baseline), hydrotherapy was associated with a significant decrease in parturient anxiety at 15 min and 45 min. In the group as a whole there were no significant differences between pre-immersion and immersion pain levels (Table 2). When participants were separated into subgroups according to pre-immersion pain level, however, there were significant differences, with pain decreasing more for women with high levels of baseline pain (≥ 70 mm) than for women with low baseline levels (≤ 50 mm) after 15 and 45 min of immersion (Table 3).

We were not able to collect data on all neuroendocrine variables for all 11 women at all time points due to our inability to draw blood specimens. There were no differences between pre-immersion and immersion cortisol levels. However, cortisol levels decreased twice as much after 15 min of immersion for women with high baseline pain as for those with low baseline pain (Table 3). βE levels increased for the group as a whole at 15 min of bathing but did not significantly differ between baseline and 45 min. Hydrotherapy was associated with a significant decrease in O from baseline to 15 and 45 min of immersion. Plasma V also decreased significantly from baseline to 15 and 45 min of immersion (Table 2). Neither E nor NE levels changed significantly with hydrotherapy.

CX frequency decreased significantly ($p = .04$) with bathing. All women had a positive mean PVS% at 15 min (+4.8, $n = 8$) and at 45 min (+5.2%, $n = 7$). PVS% at 15 min of hydrotherapy was significantly positively correlated with CX duration ($r = .74$, $p = .04$). This was the only statistically significant relationship between study variables.

Discussion

Our findings that anxiety significantly decreased throughout hydrotherapy for the group as a whole and that pain decreased more for women with high baseline levels than for women with low baseline levels at both measurements are congruent with our previous report in a separate group of laboring women (Benfield et al., 2001) as well as the work of others (Cammu et al., 1994; da Silva et al., 2009; Eldor et al., 1992; Lenstrup et al., 1987). However, a floor effect may have existed in the low-pain subgroup because the lower limit of the pain scale was set at zero.

Decreases in pain were mirrored by decreases in C levels for women with high baseline pain levels. At 15 min into hydrotherapy, plasma C levels had decreased twofold in women who reported high pain prior to immersion. Decreases in C during immersion, at rest, and with exercise at 60% VO_{2max} have been noted in late pregnancy (McMurray, Katz, Berry, & Cefalo, 1988). Although C levels in this sample of parturients decreased during hydrotherapy, they remained higher throughout the study than those of college-age men with

4 years of resistance training who were subjected to high-intensity resistance exercise to evoke a maximal anticipatory and psychophysiological stress response (Kraemer et al., 2005). Their mean C level at 30 min pre exercise was approximately 525nmol/L, or 19.02ug/dl, and their peak level, at 10 min post exercise, was 935nmol/L, or 33.51ug/dl. The mean C levels of women in our study were 46.23 ug/dl pre immersion, 41.77 ug/dl at 15 min of immersion, and 40.30 ug/dl at 45 min of immersion. Even with the known hypercortisolism of pregnancy and labor, this comparison suggests that labor stress in women with high subjective pain is relatively severe and that the hydrotherapy intervention may be a highly effective way to provide relief from that stress.

While hydrotherapy was associated with a decrease in C levels, it failed to reduce either plasma E or NE levels in either the total group or either of the two pain subgroups. In a prior study with a separate sample of women in labor, we found that urine catecholamine levels did not decrease significantly with a hydrotherapy intervention (Benfield et al., 2001). While some researchers have hypothesized that a decrease in catecholamine levels is the mechanism underlying the effects of hydrotherapy (Odent, 1983), our current and previous findings as well as those of other researchers suggest that dampening of the sympathetic nervous system with resulting decreases in plasma catecholamines may not be the underlying mechanism for these effects (Robertson et al., 1998; Rush et al., 1996). While the sympathetic response is beneficial for coping with brief periods of stress (seconds to 30 min), it is likely not the best indicator for the prolonged stress of labor. Still, our results must be interpreted with caution due to the small sample size and the large individual variation in catecholamine response.

βE levels increased, though not significantly, with 15 min of immersion then decreased at 45 min to levels again not significantly different from those at pre immersion. Similarly, in one study, βE levels in late pregnancy increased during immersed exercise at 60% VO_{2max} above both dry and immersed resting levels (McMurray, Berry, & Katz, 1990). However, it is uncertain which aspects of labor stress, if any, are analogous to the stress of exercise. Few previous studies have specifically evaluated maternal pain reports and plasma βE levels in labor or the effect of pain-reduction interventions on these variables. Raisanen, Paatero, Salminen, and Laatikainen (1984) found that maternal pain and plasma βE levels increased concurrently across unmedicated labor increase and were positively, though not significantly, correlated. Bacigalupo, Riese, Rosendahl, and Saling (1990) found subjective pain and plasma βE levels to be highly correlated ($p < .001$) in parturients whose cervical dilation was near 6 cm. Other researchers have found that βE and subjective pain levels both decreased after epidural analgesia (McLean, Thompson, Zhang, Brinsmead, & Smith, 1994; Raisanen et al., 1984; Scull et al., 1998) and that changes in pain scores before and during epidural analgesia were correlated with βE levels ($r = 0.84$, $p < .001$; Raisanen et al., 1984).

The increasing plasma βE levels known to exist with advancing labor may reflect the physiological stress associated with effective labor progress in addition to parturient pain. Proopiomelanocortin- (POMC) derived peptides, including βE, are present in human myometrium (Clifton et al., 1998), and the POMC gene has been identified in the human placenta at term gestation (Grigorakis, Anastasiou, Dai, Souvatzoglou, & Alevizaki, 2000). These findings point toward mechanisms of action for βE that may be separate from pain control. Specifically, βE may play a local role in labor progress. Thus, it cannot be determined whether peripheral levels of βE during labor are reflective of its role in pain control or represent locally released βE that has participated more directly in labor. Thus, while βE may have a role in pain control, it is unclear what that role is or whether, in the current study, the higher concentration of βE at15 min was related to O inhibition or decreases in uterine contractility.

As expected based on previous research (Hammerum et al., 1998), V levels decreased significantly and remained decreased throughout hydrotherapy. Unexpectedly, O levels followed the same pattern, and the frequency of uterine contractions also decreased significantly. In vitro, human myometrium is significantly more sensitive to V than to O after the onset of labor (Thornton et al., 2002). In vivo, the exogenous infusion of synthetic arginine-vasopressin (1 unit intravenous) was found to "augment an expected contraction." (Embrey & Moir 1967, p. 649). Because V acts at both O and V receptors on the myometrium, both hormones may be involved in the regulation of labor (Bossmar et al., 1994). We can, thus, speculate that the decrease in V and O concentrations during hydrotherapy was connected with the significant decrease in contraction frequency. We did not measure contraction intensity because of the infection risks associated with use of an intrauterine pressure catheter in water. Therefore, we do not know whether hydrotherapy-associated decreases in V and O levels had any effect on contraction intensity. Additionally, given the limited frequency of our sampling protocol, we may have missed the pulsatile release of O in labor (Fuchs et al., 1991; Otsuki, Yamaji, Fujita, Takagi, & Tanizawa, 1983). While the changes in V and O mimicked each other, they were not significantly correlated with each other or with subjective measures of anxiety or pain.

A positive PVS% with immersion to the chest has been shown to occur in as little as 15 min with immersed parturients (Benfield et al., 2001). As anticipated, all the women in our study had a positive PVS%, which increased slightly throughout the intervention. This finding is consistent with the findings of Katz and colleagues (1988), who investigated immersion in pregnancy, and with our prior work on hydrotherapy and labor (Benfield et al., 2001). However, the percent shift in the current study was less than that reported in our earlier study at 15 min (7.8%) and 60 min (9.6%) of hydrotherapy (Benfield et al., 2001). We can only hypothesize that slower tub filling (in the prior study they were immersed to chest upon entering the tub) and less immediate hydrostatic pressure may have resulted in the smaller amount of PVS%. In any case, our findings are congruent with the expected onset and positive direction of plasma volume shift, which are opposite the negative shift often seen with intense exercise on land.

The positive PVS% during hydrotherapy may have been associated with improved uteroplacental perfusion. Interestingly, we found that PVS% at 15 min of hydrotherapy was strongly and positively correlated with contraction duration. An inverse relationship between blood flow and contractility indicates that uterine smooth muscle is dependent on blood supply for normal metabolite levels and force production (Larcombe-McDouall, Harrison, & Wray, 1998). Perhaps as contraction frequency decreased, the perfusion between contractions increased, resulting in longer contraction duration. Theoretically, intensity should also increase in this case, but this remains to be studied.

Hydrotherapy has been reported to improve uterine dystocia and decrease the need for augmentation and epidural use (Cluett et al., 2004). Dystocia and dysfunctional labor are thought to be associated with more severe pain and to increase the likelihood of a request for epidural analgesia (Hess, Pratt, Soni, Sarna, & Oriol, 2000; Panni & Segal, 2003). Severe pain and lack of cervical dilatation beyond 5 cm are reported to improve with hydrotherapy (Odent, 1983). It seems reasonable to speculate that decreased contraction frequency and improved uterine profusion could facilitate a return to normal contraction synchrony, intensity and frequency, thereby decreasing pain and dysfunction. Thus, positive PVS% may merit further investigation as an intervention for labor dysfunction.

Finally, the effect of water temperature must be taken into account. Most immersion studies in men have been conducted at a thermoneutral temperature of 34–45°C because this has the least effect on the cardiovascular system. We selected a temperature of 37°C because it

approaches 36°C, the most frequent mean temperature chosen by laboring women, and it is the most frequently used temperature in hydrotherapy studies in labor (Benfield, 2002; Schorn et al., 1993). The warmer temperature may affect endocrine levels as well as peripheral circulation, contributing to differences in study findings.

Study strengths include the within-subjects study design, which controls for the large individual variability in stress hormone baseline and response levels and provides considerably more power than would between-subjects designs. Strict adherence to study inclusion criteria during antepartal consent and at labor admission added rigor by controlling for extraneous variables known to affect labor pain and uterine contractility. It is particularly important that no participant received analgesia during study participation so that changes more clearly reflect the intervention effects rather than those of a narcotic. The 1 hr 30 min timeframe during early labor in which data were collected is most stable window of active labor in which to study the intervention effects.

Study results are limited by the short study period, which did not allow continued evaluation of the length of intervention effect. Additionally, we were unable to stratify findings based on demographics or parity because of the small sample size, although these factors affect both maternal perception of the experience and labor progress.

While our small sample size also limits interpretation of the findings, and the precise psychophysiological mechanisms of hydrotherapy remain unknown, our findings support the hypothesis that anxiety and pain decrease with bathing, particularly in women with high levels of pain. It may be that the central PVS% associated with immersion plays a role in reducing anxiety and pain. The effects of hydrotherapy are rapid, occurring within 15 min of a parturient entering the tub. This period of time may be adequate to allow for effects on the hypothalamic pituitary adrenal axis, as evidenced by decreases in cortisol levels. Although anxiety, vasopressin and oxytocin are temporally synchronized they are not statistically correlated in this sample. During hydrotherapy, uterine contraction frequency decreases, along with oxytocin and vasopressin, while contraction duration increases as plasma shifts into the vascular system.

As yet unknown modulatory relationships may exist between the complex psychophysiological processes in normal labor and the neuroendocrine responses to stress that are affected by hydrotherapy. Large, well-controlled randomized studies are needed, as along with additional smaller studies, to clarify the mechanisms of hydrotherapy action and its effects on labor progress. Knowledge gained from this and future studies can be directly applied in clinical practice by nurses, midwives and physicians caring for women in labor who desire noninvasive, low-risk yet efficacious anxiety and pain intervention.

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Table 1

Demographic Characteristics for Participants (N = 11)

Characteristic	*n* (%)
Ethnicity	
African American	6 (55)
White	3 (27)
Hispanic	1 (9)
Native American	1 (9)
Married	6 (55)
Employed	6 (55)
	Mean (range)
Age (years)	24.5 (21–33)
Education (years)	13.5 (10–18)

Table 2

Mean (SD) for Anxiety, Pain, Oxytocin, Vasopressin, β-endorphin and Cortisol Levels at Baseline (0) and at 15 and 45 min of Hydrotherapy (Wilcoxon Signed Ranks Test)

Variable	Timepoint			0–15 min			0–45 min		
	0	15 min	45 min	*n*	*z*	*p*	*n*	*z*	*p*
Anxiety (mm)	51.3 (17.51)	33.1 (20.97)	29.3 (22.41)	9	2.49	.01	9	1.96	.03
Pain (mm)	55.9 (23.16)	51.1 (19.99)	53.6 (21.84)	9	0.83	.41	9	0.59	.55
Oxytocin (pg/ml)	192.5 (86.97)	152.7 (96.18)	153.9 (93.34)	9	2.31	.01	8	1.96	.03
Vasopressin (pg/ml)	5.1 (2.37)	4.0 (1.89)	4.0 (1.84)	9	2.31	.01	8	2.24	.01
β-endorphin (ng/ml)	0.18 (0.07)	0.33 (0.22)	0.25 (0.12)	9	1.96	.05	8	0.91	.36
Cortisol (ug/dl)	46.2 (18.31)	41.8 (13.77)	40.3 (10.43)	9	1.24	.21	9	1.36	.17

Note. Anxiety was measured with a visual analog scale for anxiety (VASA); pain was measured with a visual analog scale for pain (VASP).

Table 3

Comparison of Mean *(SD)* Changes in Pain and Cortisol Levels from Baseline (0) to 15 and 45 Min of Hydrotherapy in Low and High pre-Immersion (Baseline) Pain Groups (Mann-Whitney U Test)

Variable	Low Pain		High Pain		*z*	*p*
	n	*M (SD)*	*n*	*M (SD)*		
Pain (mm)						
0–15 min	5	3.2 (10.52)	6	30.3 (26.53)	2.29	.01
0–45 min	5	2.8 (14.08)	6	21.7 (22.87)	1.83	.04
Cortisol (ug/dl)						
0–15 min	5	3.1 (10.72)	4	6.2 (7.97)	0.49	.73
0–45 min	5	6.9 (11.74)	4	4.6 (10.15)	0.25	.91

Note. Pain was measured with a visual analog scale for pain (VASP). The low-pain subgroup had baseline VASP scores ≤ 50 mm; the high-pain subgroup had baseline VASP scores ≥ 70 mm.