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Preterm infant weight gain is increased by massage therapy and exercise via different underlying mechanisms

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ABSTRACT

Objective: To compare the effects of massage therapy (moderate pressure stroking) and exercise (flexion and extension of limbs) on preterm infants' weight gain and to explore potential underlying mechanisms for those effects.
Methods: Weight gain and parasympathetic nervous system activity were assessed in 30 preterm infants randomly assigned to a massage therapy group or to an exercise group. Infants received 10 min of moderate pressure massage or passive flexion and extension of the limbs 3 times per day for 5 days, and EKGs were collected during the first session to assess vagal activity.
Results: Both massage and exercise led to increased weight gain. However, while exercise was associated with increased calorie consumption, massage was related to increased vagal activity.
Conclusion: Taken together, these findings suggest that massage and exercise lead to increased preterm infant weight gain via different underlying mechanisms.

1. Introduction

Prematurity is among the leading causes of infant morbidity [1]. Supplementary stimulation programs in the NICU including massage therapy (moderate pressure stroking) and exercise (passively moving the limbs into flexion and extension) can improve preterm infant development, including increased weight gain [2,3]. Inasmuch as most preterm infant massage studies have combined tactile (massage) and kinesthetic (exercise) stimulation, it is unclear whether the tactile or the kinesthetic component is responsible for the increased weight gain observed in these studies.

Preterm infants receiving a combined tactile–kinesthetic stimulation protocol show increased weight gain [2,4]. Similarly, studies utilizing either only kinesthetic stimulation [3,5] or only tactile stimulation [6] have shown increased weight gain, suggesting that both the tactile and kinesthetic components are effective by themselves in promoting preterm infant weight gain.

A potential mechanism underlying preterm infant weight gain following tactile–kinesthetic stimulation may involve the stimulation of baroreceptors and mechanoreceptors leading to the activation of vagal afferent and efferent pathways involved in the parasympathetic control of the cardiovascular and gastro-intestinal systems [7,8]. This mechanism is supported by studies revealing that a combined tactile/kinesthetic stimulation protocol elicits increases in cardiac vagal activity that are associated with increased gastric motility and preterm infant weight gain [7–9]. Tactile and kinesthetic stimulation may promote preterm infant weight gain via different underlying mechanisms. While preterm infant cardiac vagal activity has yet to be assessed independently for kinesthetic and tactile stimulation, studies with adults suggest that passive exercise, which is similar to the kinesthetic stimulation protocol used with preterm infants, inhibits cardiac vagal activity [10,11], while moderate pressure massage therapy, which is analogous to the tactile stimulation protocol used with preterm infants, increases cardiac vagal activity [12]. The aim of this study was to compare the effects of the tactile and the kinesthetic stimulation protocols on preterm infant weight gain while exploring cardiac vagal activity as a potential underlying mechanism.

2. Methods

2.1. Participants

Following institutional review board approval and parental informed consent, medically stable preterm neonates were recruited from a neonatal intensive care unit. Preterm infants were considered eligible for recruitment if: a) their gestational age (GA) at birth was between 28 and 32 weeks; b) their birth weight was between 800 and

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1400 g; c) their NICU stay at study entry was 15–60 days; and d) their weight at study entry was between 1000 and 1500 g. Preterm infants were excluded if: a) they had congenital malformations, chromosomal aberrations, congenital infections, genetic anomalies, congenital heart malformations, and/or central nervous system dysfunction (e.g., intraventricular hemorrhage or a history of seizure); b) they were HIV positive; c) had a history of maternal alcohol/illicit drug use (as determined by the mother's reported history, medical records, and universal drug screen performed prior to delivery), syphilis, or hepatitis B, or d) they required surgery. All infants were bottle-fed premature infant formula. Infants were stratified based on gender, birth weight, gestational age at birth, and days on the NICU prior to group assignment. Preterm neonates meeting recruitment criteria were randomly assigned to a tactile stimulation group or a kinesthetic stimulation group. Recruitment continued until 30 preterm infants ($n = 15$ in each group) completed the study. Data from 5 preterm neonates ($n = 3$ kinesthetic, $n = 2$ tactile) who were discharged before completing the 5-day treatment protocol were excluded from the study. There were no systematic differences in diagnoses or treatments between groups or between infants who completed and did not complete the study.

Relevant medical history was gathered from the infant's medical charts (measured by NICU nurses) including mean weight gain per day in grams, percent weight gain (mean weight gain per kilogram per day) and mean calories consumed per kilogram per day. Data were collected and averaged for the 2 days prior to the beginning of treatment (baseline) and the 5 days of treatment (treatment). Electrocardiograms (EKGs) were collected by researchers blind to the infant's group assignment for a total of 30 min (10 min baseline, 10 min treatment, and 10 min post-treatment). Inasmuch as only short term, heart rate variability changes have been observed following tactile–kinesthetic stimulation [8], EKGs were collected to assess short term changes in heart rate variability on the morning of the third day of the study, as this marked the midpoint of the study treatment protocol. All infants continued to receive standard nursery care during the course of the study.

2.2. Treatment

Supplementary stimulation (tactile or kinesthetic) was provided for three 10-min periods per day for 5 days, 1 h after feeding by research associates trained in the study protocol. Training involved watching a video of the protocol followed by a series of observation and practice sessions. Reliability was assessed before the study and reevaluated throughout the study to ensure protocol compliance. Each neonate received treatment from multiple research associates to ensure that treatment effects were the result of the treatment protocol and not from any particular individual.

Neonates in the tactile stimulation group were placed in a prone position and stroked with moderate pressure (sufficient to produce a slight indentation in the skin) as in the Field et al. tactile stimulation protocol [4]. The tactile stimulation was applied: a) from the top of the head to the neck and back to the top of the head; b) from the neck across the shoulders and back to the neck; c) from the upper back to the waist and back to the upper back; d) from the thigh to the foot to the thigh on both legs; and e) from the shoulder to the hand to the shoulder on both arms. Each stroking motion lasted 10 s for a total period of 10 min. Hypoallergenic baby oil was applied to reduce friction.

Neonates in the kinesthetic stimulation group were placed in a supine position and their limbs were flexed and extended as in the Moyer–Mileur protocol [3]. The kinesthetic stimulation was applied by: a) flexing and extending each arm at the elbow; b) flexing and extending each hand at the wrist; c) flexing and extending each leg at the knee; d) flexing and extending each foot at the ankle; and e) flexing and extending both legs together (as in a bicycling motion). Each flexion/extension motion lasted 10 s, for a total period of 10 min.

2.3. EKG

Electrocardiograms (EKGs) were collected to estimate vagal activity as a potential underlying mechanism for weight gain following tactile/kinesthetic stimulation. EKGs were collected from each infant using a UFI Model SRS2004/d-SP Electro-physiology Acquisition System, by placing three disposable, pre-wired silver chloride neonatal electrodes on the preterm infant's chest and back. The EKG signal was filtered between 1 Hz and 100 Hz, amplified using a gain of 2000 and sampled at a rate of 1000 Hz. Following manual artifact correction, EKG data were converted to R-to-R-wave intervals (inter beat intervals, IBI) to the nearest millisecond and analyzed to obtain the high frequency component of heart rate variability, defined as 0.3–1.3 Hz for preterm infants (Bohrer & Porges, 1982), using data acquisition and analysis software (Acq Knowledge software V.3.5, Biopac Systems Inc.). The high frequency component of heart rate variability, HF, provides a non-invasive assessment of cardiac vagal activity [13].

Table 1
Study entry characteristics (means and standard deviations in parentheses under means).

	Kinesthetic $n = 15$	Tactile $n = 15$		
Birth weight (g)	1156.53 (180.55)	1232.67 (186.57)	$F(1, 29) = 1.29$	$p =$ n.s.
Gestational age (weeks)	29.40 (1.59)	29.07 (1.83)	$F(1, 29) = 1.29$	$p =$ n.s.
Birth length (cm)	38.00 (2.20)	38.89 (1.92)	$F(1, 29) = 1.34$	$p =$ n.s.
Head circumference (cm)	26.32 (1.92)	27.39 (1.99)	$F(1, 29) = 2.19$	$p =$ n.s.
Ponderal index	2.12 (0.24)	2.13 (0.23)	$F(1, 29) = 0.01$	$p =$ n.s.
Mother's age	28.67 (6.45)	29.20 (6.53)	$F(1, 29) = 0.05$	$p =$ n.s.
Mother's SES	4.62 (1.04)	4.08 (0.90)	$F(1, 29) = 1.85$	$p =$ n.s.
Ethnicity				
White	0%	0%	$X^2(1) = .71$	$p =$ n.s.
African American	47%	40%		
Hispanic	53%	60%		
Gender				
Male	40%	60%	$X^2(1) = .27$	$p =$ n.s.
Female	60%	40%		
Days on NICU	36.67 (11.50)	33.20 (14.38)	$F(1, 29) = 0.53$	$p =$ n.s.