



# Oral and nonoral sensorimotor interventions facilitate suck–swallow–respiration functions and their coordination in preterm infants

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## ABSTRACT

**Background:** Preterm infants are at high risk of encountering oral feeding difficulties. Early sensorimotor interventions may improve oral feeding skills in preterm infants.

**Aim:** To further explore the effects of an oral (O), tactile/kinesthetic (T/K), and combined (O + T/K) sensorimotor intervention on preterm infants' nutritive sucking, swallowing and their coordination with respiration. **Study design:** Seventy-five infants (29 [0.3, standard error of mean, SEM] weeks gestation, 49 males/26 females) were randomly assigned to an O group involving sensorimotor input to the oral structures; a T/K group involving sensorimotor input to the trunk and limbs; a combined (O + T/K) group; and a control group.

**Outcome measures:** Stage of sucking, suction and expression amplitudes (mm Hg), suck–swallow ratio, stability of suck–swallow interval, and swallow–respiration patterns.

**Results:** The O group had significantly more advanced sucking stages, and greater suction and expression amplitudes than controls [ $p \leq 0.035$ , effect size (ES)  $> 0.6$ ]. The suck–swallow ratio and stability of suck–swallow intervals did not significantly differ among groups ( $p \geq 0.181$ ,  $ES \leq 0.3$ ). The three interventions led to fewer swallows bracketed by prolonged respiratory pauses compared to controls (pause–swallow–pause,  $p \leq 0.044$ ,  $ES \geq 0.7$ ). The T/K and combined (O + T/K) groups had greater occurrence of swallows bracketed by expiration than the control and O groups (expiration–swallow–expiration,  $p \leq 0.039$ ,  $ES \geq 0.3$ ).

**Conclusion:** The O intervention enhanced specific components of nutritive sucking. All three interventions resulted in improved swallow–respiration coordination. Sensorimotor interventions have distributed beneficial effects that go beyond the specific target of input.

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## 1. Introduction

Oral feeding in the neonatal period requires precise coordination between sucking, swallowing and breathing [1]. Preterm infants often have difficulty in establishing this key coordinative relationship [1]. Hence, they are tube fed and are kept in hospital until they are able to safely meet their nutritional requirements orally, while maintaining adequate daily weight gain without cardiorespiratory compromise [2]. Our studies suggest that early sensorimotor interventions may improve oral feeding skills and facilitate suck–swallow–respiration in preterm infants [3,4].

Many current interventions to improve sucking, swallowing, and their coordination with respiration focus on promoting the neural

maturation of these processes [3–6]. Our earlier work has shown that an oral (O), tactile/kinesthetic (T/K), and combined oral and tactile/kinesthetic (O + T/K) sensorimotor intervention, administered before the start of oral feeding, accelerated the transition from introduction to independent oral feeding [4]. Specifically, all three interventions improved proficiency (percent volume taken in first 5-minutes), volume transfer (percent total volume taken) and rate of transfer (ml/min), compared to controls [4]. Nutritive suck, suck–swallow and swallow–respiration coordination appear to be key components underlying these improved oral feeding outcomes [4]. Knowledge on how these underlying mechanisms mediate these vital coordinative functions is very limited. In our previous work, we have found that oral sensorimotor input improves nutritive sucking [3], however the impact of oral and particularly non-oral sensorimotor input (tactile/kinesthetic sensorimotor input to the trunk and limbs) on sucking, swallowing, and respiration and their coordination has not been investigated. Furthermore, given multiple points of interaction in the nervous system [7], we hypothesize that multiple stimulation sites may potentially impact common underlying systems or may in fact provide multiplicative effects on these coordinative functions.

**Abbreviations:** ES, Effect size; E, Expiration; GA, Gestational age; I, Inspiration; O, Oral; P, Pause; PMA, Postmenstrual age; SEM, Standard error of mean; Sw, Swallow; T/K, Tactile/kinesthetic.

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Therefore, the purpose of this current study was to further explore whether: 1) preterm infants who receive an O, T/K, or combined (O + T/K) intervention, before the introduction of oral feeding, will demonstrate more advanced nutritive sucking, suck–swallow and swallow–respiration coordination than controls. Specifically, 1a) they will exhibit more mature sucking stages, and greater suction and expression amplitudes, 1b) they will demonstrate an equal suck to swallow ratio and a stable suck–swallow interval, and 1c) they will have a more mature swallow–respiration pattern than controls. 2) Preterm infants who receive a combined (O + T/K) intervention will demonstrate more advanced nutritive sucking, suck–swallow and swallow–respiration coordination than those who receive an O or T/K intervention singly.

## 2. Methods

### 2.1. Participants

Participants were recruited from the nursery at Texas Children's Hospital, Houston, TX. Eligibility included infants: 1) born between 26 and 32 weeks gestational age (GA); 2) of appropriate size for GA; 3) receiving only tube feedings; 4) with no congenital anomalies; and 5) with no chronic medical complications including severe bronchopulmonary dysplasia, intraventricular hemorrhages III or IV, periventricular leukomalacia, or necrotizing enterocolitis. The study was approved by the Institutional Review Board for Human Subjects at Baylor College of Medicine and Affiliated Hospitals.

### 2.2. Procedures

After parental consent was obtained, infants were randomized into an O, T/K, combined (O + T/K), or control group using a stratified blocked randomization. A block stratification by GA (26–29 and 30–32 weeks GA) was used to ensure that all four groups had equal GA distribution, and stratification by time (three month intervals) was done to make certain each group had balanced distribution of attending neonatologists. All participants were followed from the start of the study until hospital discharge.

Similar to our previous investigations [3,4,6] the O intervention consisted of sensorimotor input to the oral structures: specifically, perioral stimulation to the cheeks, lips, and jaw for 7 min, intraoral stimulation to the gums and tongue for 5 min, and nonnutritive sucking on a pacifier for 3 min [3,4,6]. The 15-minute O intervention was administered twice a day (total: 30 min per day). The infants were in supine position in the incubator throughout the O intervention. The T/K intervention consisted of stroking the body starting from the head, followed by the neck, shoulders, back, legs, and arms for 10 min and passive range of motion of the arms and legs for 5 min [8]. The 15-minute T/K intervention was administered twice a day (total: 30 min per day). The infants were in the incubator, in prone and supine positions, respectively, during the T/K intervention. This regimen was selected because at least 15min/day of O or T/K intervention had beneficial effects on oral feeding performance and motor activity, respectively [3,4,8]. The combined (O + T/K) intervention consisted of the same 15 min of O and 15 min of T/K intervention, described above. Each type of intervention was administered once a day (total: 30 min per day), in random order. For the control intervention the researcher (SF) placed her hands in the incubator but did not touch the infant for 15 min, twice a day (total: 30 min per day). The control intervention was designed to eliminate possible effects of the daily presence of the researcher at the bedside.

All interventions were commenced 48 h following discontinuation of nasal continuous positive airway pressure, and administered for 10 days, within a 14-day period. Interventions were provided 30 min prior to a tube feeding, with a minimum 3-hour interval

between each daily session, and when infants were clinically stable determined by nurses' recommendation. Interventions were stopped if infants had an episode of apnea, bradycardia, oxygen desaturation, fussing, crying, or emesis. All interventions were administered in the incubator by the same researcher. A screen was placed around the bedside in order to 'blind' family members and caregivers to group assignment.

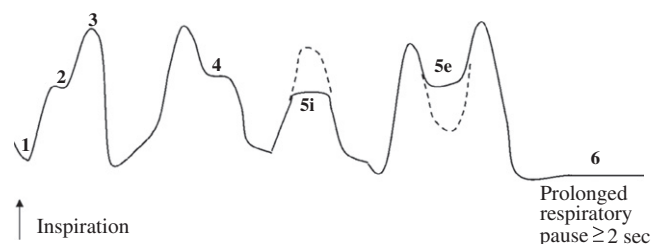
Sucking, swallowing and respiration were monitored once during three oral feeding sessions, when infants were taking 1–2, 3–5, and 6–8 oral feedings per day. The management of oral feeding was left to the attending neonatologists' discretion. Nurses were responsible for feeding the infants in their customary manner. Oral feeding sessions were no longer than 20 min, per nursery protocol.

### 2.3. Outcomes

Nutritive sucking skills were assessed using a 5-point *stage of sucking* scale defined by Lau et al. [9]. Stage 1, represents an immature/disorganized sucking pattern with no suction, arrhythmic expression, and/or arrhythmic alternation of suction/expression. Stages 2–4, represent more mature sucking patterns, with suction emerging, more rhythmic expression, and/or more rhythmic alternation of suction/expression. Stage 5, represents a mature sucking pattern with rhythmic alternation of suction/expression, similar to that of full term infants. *Suction and expression amplitudes* (mm Hg) were also monitored.

Suck–swallow coordination was assessed using *suck to swallow ratio* defined as number of expressions over number of swallows, and *stability of the suck–swallow interval* defined as the time (seconds) from peak expression to swallow, using the coefficient of variation (standard deviation of the mean interval divided by the mean interval). These outcomes were selected because a 1:1 suck–swallow ratio and a stable suck–swallow interval (i.e. smaller coefficient of variation) reflect more mature suck–swallow coordination [10–12].

Respiration is always inhibited to accommodate the swallow in all species including infant and adult humans [13]. Swallow–respiration coordination was assessed by identifying the respiratory phase that immediately preceded and followed the swallow. The mean percent occurrence of particular *swallow–respiration patterns* was monitored using a 6-pattern classification developed by Lau et al., [14] which included: 1) end expiration–swallow–start inspiration (end E–Sw–start I); 2) inspiration–swallow–inspiration (I–Sw–I); 3) end inspiration–swallow–start expiration (end I–Sw–start E); 4) expiration–swallow–expiration (E–Sw–E); 5i) swallow interrupt inspiration (Sw–interrupt I); 5e) swallow interrupt expiration (Sw–interrupt E); and 6) swallow occurring during a prolonged respiratory pause of  $\geq 2.0$  s (P–Sw–P, Fig. 1). We operationally defined a prolonged respiratory pause as  $\geq 2.0$  s, based on work by Bamford and colleagues who found normal breath-to-breath intervals that ranged between 1.2–2.0 seconds during feeding epochs in term infants [10].



**Fig. 1.** Swallow–respiration patterns. Pattern 1 – start inspiration–swallow–end expiration (start I–Sw–end E); pattern 2 – inspiration–swallow–inspiration (I–Sw–I); pattern 3 – end inspiration–swallow–start expiration (end I–Sw–start E); pattern 4 – expiration–swallow–expiration (E–Sw–E); pattern 5i – swallow interrupts inspiration (Sw–interrupt I); pattern 5e – swallow interrupts expiration (Sw–interrupt E); and pattern 6 – pause–swallow–pause (P–Sw–P, swallows occurring at cessation of respiration  $\geq 2$  s).

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