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Comparison of tongue muscle characteristics of preterm and full term infants during nutritive and nonnutritive sucking

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ABSTRACT

Background: Independent oral feeding requires coordination of suck, swallow and breathe and the lingual musculature plays a significant role in this coordinative action. However, clinical benchmarks of lingual function fundamental to successful feeding have not been explored.
Aims: The present study tests our model for quantifying infant lingual force and size and compares the muscle measures of interest in two cohorts: healthy full-term infants (FT) ($N = 5$) and healthy preterm infants (PT) ($N = 6$).
Method: Using an instrumented pacifier and bottle nipple, we determined the resultant compressive forces applied to the nipple by the tongue during nutritive (NS) and nonnutritive sucking (NNS). Muscle size was estimated from measures of posterior tongue thickness using ultrasonography.
Results: After controlling for weight and post menstrual age, statistically significant differences were found between FT and PT infants beginning to feed for NNS frequency and NS tongue force. Clinically significant differences were detected for NNS tongue force and posterior tongue thickness. Additionally, PT infants demonstrated a significant difference in mean tongue force between NS and NNS and FT infants did not. FT infants demonstrated a significant difference in mean frequency between NS and NNS and PT infants did not. Linear regression indicated that mean posterior tongue thickness alone predicted 55% of the variance in NS force.
Conclusions: Results demonstrate the feasibility of our approach and suggest that infant tongue muscle characteristics necessary for successful feeding differ between healthy full term infants and preterm infants who are beginning oral feeding.

1. Introduction

Safe and efficient oral feeding is a critical milestone for infants in the Neonatal Intensive Care Unit (Pickler, 2004). The transition from tube feeding to oral feeding is a particular challenge for preterm infants (Bu'Lock, Woolridge, & Baum, 1990)

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and has a direct impact on financial costs as hospital discharge can be delayed if infants demonstrate inability to transition from tube feeding to oral feeding (Lau & Schanler, 2000; Vandenberg, 1990). Underdeveloped oral-motor skills (Lessen, 2011) including reduced muscle tone and tongue strength (Bosma, 1972) are thought to contribute to the preterm infant's oral feeding difficulties.

Independent oral feeding requires coordination of suck, swallow and breathe and the process is commonly described as a sequence of events or phases. The preparatory, or oral phase of the swallow, involves compression and then expression of fluid from the nipple and lingual transport of the fluid (Wolf & Glass, 1992). The tongue seals the oral cavity to produce the positive and negative pressure required for expression and works in conjunction with the lips, jaw, soft palate and hard palate to derive the critical volume of fluid necessary to initiate the swallow (da Costa, van den Engel-Hoek, & Bos, 2008). The fluid is then carried, via the tongue, to the valleculae to initiate the swallow. The pharyngeal phase of the swallow is initiated when the fluid is propelled by the action of the posterior tongue and the contraction of the pharyngeal constrictor muscles. The sensory receptors of the soft palate, pharyngeal walls, faucial arches and the tongue play a significant role in this phase, as the combined inputs activate the ensuing complex motor events. The esophageal, or final phase of the swallow, marks the transfer of fluid from the mouth to the stomach (Wolf & Glass, 1992). In considering the phases of the infant swallow, it becomes clear that the tongue contributes significantly to the necessary coordinative actions that occur during the oral and pharyngeal phases of the swallow (da Costa et al., 2008; Miller & Kang, 2007)

When skeletal muscle, such as the tongue, is not used to its usual capacity neuromuscular changes occur (Burkhead, Sapienza, & Rosenbek, 2007; Lieber, 1992). Using animal models, researchers have documented neuromuscular changes of the rat tongue resulting from artificial rearing practices. In each study, artificially reared pups were fed through gastric cannula while freely engaging in nonnutritive sucking (i.e. pacifier); properties of tongue musculature known to be negatively impacted by disuse were measured and compared to dam-reared pups. Significant differences in muscle were noted in the artificially-reared group and included a change in the contractile properties of the muscle, as well as a reduction in number of muscle fibers (Kinirons, Shall, McClung, & Goldberg, 2003). Subsequent studies have shown that these changes persist into adulthood (Moore, Goldberg, & Shall, 2007). Retarded hypoglossal motoneuron growth in artificially reared versus dam reared rat pups has also been demonstrated suggesting changes in the nervous system driving the muscle (Smith, McClung, & Goldberg, 2006). Researchers speculated that similar changes might also be occurring in the tongue muscle of premature infants artificially fed for extended periods of time. However, it is not clear whether the neuromuscular changes described in animal studies correlate with decreased function.

It is not known how well results of animal studies can be generalized to human infants. In addition, it is currently uncertain whether tongue muscle size indeed decreases in preterm infants and this relative atrophy cannot be examined directly. However, it would be clinically important to better understand the relationship between tongue muscle size and force in the preterm infant tongue since this relationship would certainly impact efficiency of feeding performance. Consequently, we began to explore possible instrumentation techniques for direct measurement of infant lingual properties fundamental to function, susceptible to disuse and currently unexplored relative to infant feeding. To that end, we present a novel and noninvasive approach for studying muscle properties (i.e. muscle force and thickness, as an indicator of size) that support preconditions for safe, efficient suck and swallow. The assessment methods we describe objectively measure tongue muscle attributes critical for successful oral feeding and provide pilot data necessary to determine if further study is warranted and if interventions should be directed at these variables.

2. Aims

The purpose of the present study was to compare a cohort of healthy full term infants to a group of healthy preterm infants with respect to infant tongue muscle force during nutritive and nonnutritive sucking. Because our approach to investigating functional properties of infant tongue muscle was novel we included full term infants as a frame of reference for all our measures of interest. Additionally, we were interested in exploring tongue force in the context of both nutritive and nonnutritive sucking since the goals, rhythm, rate and suck–swallow ratio have been shown to differ significantly in healthy term infants (Mizuno & Ueda, 2006; Wolff, 1968; Wolf & Glass, 1992).

Our method for quantifying tongue force was of particular interest as it permits real-time acquisition of tongue induced movement at the nipple interface. Previous investigations of sucking strength have been dependent on measures of sucking pressure yielding derivative knowledge about strength (Lang et al., 2011; Medoff-Cooper, Bilker, & Kaplan, 2001). Here we derived sucking strength from direct measures of tongue force. To the best of our knowledge, this is the first time infant tongue force has been directly measured during nutritive sucking.

An additional aim was to compare mean values of posterior tongue thickness between our two populations of interest. The posterior portion of the tongue was selected for imaging as it is considered to be the aspect of the infant tongue most responsible for moving a bolus to the valleculae to initiate a swallow (Miller & Kang, 2007). Including tongue thickness as an additional muscle measure permitted initial investigation into the relationship between tongue force and muscle thickness in neonatal swallowing; a relationship documented for masseter muscle thickness and bite force magnitude (Raadsheer, van Eijden, van Ginkel, & Prahl-Andersen, 1999), but unexplored in the infant skeletal tongue muscle.

A final aim of the study was to test our model for quantifying infant lingual properties fundamental to function and currently unexplored relative to preterm infant feeding. Our approach includes measurement of actual tongue force during nutritive sucking – which has not been compared between preterm and full term infants. Our approach for investigating