Development of an Infant Head-neck Musculoskeletal Model to Elucidate Asphyxia Risk
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Summary

This study aims to develop an infant head-neck musculoskeletal model to examine the biomechanical factors influencing infant head-neck flexion, a posture associated with Sudden Unexpected Infant Death (SUID) risk. Motion capture data from a surrogate doll was incorporated into a novel scaled OpenSim musculoskeletal model to examine head-neck flexion and extension. Initial results indicate higher-than-expected muscle forces, highlighting the challenges of scaling requirements necessary to address the infant population and prompting further model refinement to improve accuracy in replicating infant morphology.

Introduction

There are nearly 3600 SUID cases in the US each year from causes that are poorly understood. Of these, the majority of infants are less than 4 months old and nearly one-third of all SUIDs involve asphyxia. [1,2]. Previous studies into factors affecting SUID risk suggest a relation to body position and infant-product interaction [3]. Studies assessing body position have indicated a flexed head-neck (chin-to-chest) position, promoted by the occupancy of some infant products, inhibits normal breathing and obstructs the airway. To better understand how infants may achieve this chin-to-chest position, we must understand the biomechanical factors at play within an infant's musculoskeletal (MSK) system and the contributing factors of their environment.

This study aims to develop a novel infant head-neck musculoskeletal computational model that can be used to quantify the muscle forces required during head/neck flexion and extension. The goal of the model is to understand the impact of product designs and surface angles on the ability to achieve and correct from a chin-to-chest posture.

Methods

Motion capture data was collected using a surrogate doll with head mass and size matching the 50th percentile for infants aged 0-6 months. While positioned supine on a flat surface, the doll's head was manually manipulated from a starting position with the head flat against the surface to the final chin-to-chest position over a 5-s period. Eight Vicon (Oxford, UK) cameras recorded the motion at 100Hz using a seven-marker set defined by a preconstructed MSK model of the head-neck defined by Mortensen et al [4]. Motion capture data was imported to OpenSim and linked to the Mortensen Hyoid head-neck model which was then scaled to the dimensions of the surrogate doll with head mass adjustments for accurate muscle force simulation. Subject-specific cranial meshes, generated from infant decedent CT scans (New Mexico Decedent Image Database, 2024), were used to validate scaling. Static Optimization (SO) was performed on the scaled model to predict muscle forces and activation during the chin-to-chest activity. The muscle force for each muscle in the flexor and extensor group respectively was summed to assess the overall muscle forces achieved over the 5-s movement.

Results and Discussion

We successfully developed a scaled OpenSim model (**Figure 1**), representative of an infant's unique anatomy. The flexor muscles were active during the flexion portion of the simulated activity, and the extensor muscles were active during the extension portion of the simulated activity. We noted larger than expected forces in these muscle groups, and intend to adjust parameters in the cervical spine to better replicate infant morphology and to validate the model. After validation of the model, we will use this to understand the muscular demands on infants to achieve and self-correct from a chin-to-chest position in a variety of inclined postures.

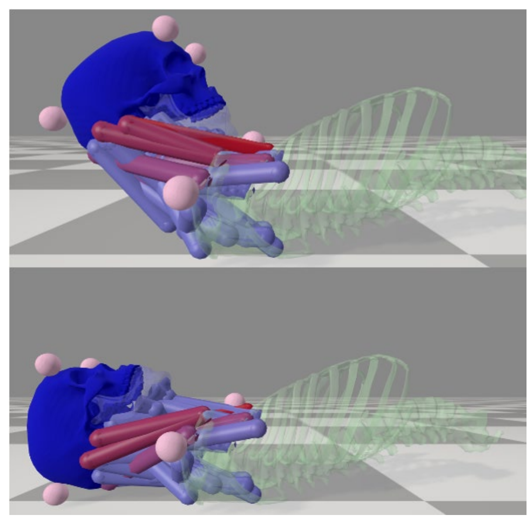

Figure 1: Novel infant head/neck musculoskeletal model developed in OpenSim, showing (top) the flexion activity and (bottom) the extension activity on a flat surface.

Conclusions

Achieving and self-correcting from a chin-to-chest posture has serious implications for asphyxiation-related safety for infants. The development of this novel OpenSim model will help elucidate the muscular demands of common infant postures in maintaining airway patency.

References

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