Infant Car Seats/Carriers Induce Head-Neck and Torso-Pelvis Flexion

Erin M. Mannen[1], Danielle N. Siegel[1], Sarah Goldrod[1], John Carroll[2], Brandi Whitaker[2], Trevor Lujan[1], Christopher Wilson[1]
[1]Boise State University, Boise, Idaho, United States; [2]Arkansas Children's Research Institute, Little Rock, Arkansas, United States
Email of Presenting Author: ErinMannen@BoiseState.edu

Disclosures: E. Mannen: 8; Journal of Biomechanics. D. Siegel: None. S. Goldrod: None. J. Carroll: None. B. Brandi Whitaker: None. T. Lujan: None. C.R. Wilson: None.

INTRODUCTION: The musculoskeletal and motor development of infants is largely affected by their environment,[1] which varies from being held in arms, lying on a firm flat surface, to spending time in various nursery products, like an infant car seat (referred to as an infant carrier when used outside of the car). Research has shown that excessive time in infant carriers has been linked to increased rates of deformational plagiocephaly,[2] and decreased oxygen saturation levels,[3] leg movements,[4] and muscle activity.[5] Despite the abundance of infant products, biomechanics of infants within commercial products is a neglected research area.[6] With some U.S. infants spending the majority of their time in commercial products,[7] it is important to understand how an infant's muscle activation and body position are affected by products to further understand development and safety in products. Therefore, the purpose of this study was to determine an infant's muscle activation and body position in a commercial infant carrier compared to a firm flat playmat.

METHODS: Thirteen healthy infants (4.2±1.4 mos; 7M/6F) participated in this IRB-approved study. Surface electromyography (EMG) electrodes (Delsys, 2000Hz) recorded muscle activity from the cervical paraspinals (CP), erector spinae (ES), abdominal muscles (AB), and quadriceps (QUAD) (**Fig. 1C**). A retroreflective marker-based motion capture system (Qualisys, 100Hz) tracked infant kinematics using custom 3-marker (6.5mm) rigid body clusters on the head, torso, and pelvis (**Fig. 1C**). Infants laid supine on a firm flat playmat (**Fig. 1A**) and unrestrained in a commercial infant carrier (**Fig. 1B**), each for three minutes for data collection. Using MATLAB, the EMG signal was filtered, and the mean was taken over 60 seconds of each condition for each muscle group and normalized to a percent of the playmat condition. The kinematic data was analyzed using MATLAB to determine the head-neck and torso-pelvis flexion by finding the angular orientation between adjacent body segments from the local coordinate systems defined by rigid body clusters on each segment in an ideal position (head, torso, and pelvis visually aligned in the sagittal plane). All angles were normalized to the playmat condition to account for each infant's anatomical differences in an unconstrained flat surface lying position. Paired t-tests ($p<0.05$) were completed to compare the carrier results to the playmat.

RESULTS: The mean muscle activation for the carrier was 87% of the playmat for the CP, 75% for the ES, 110% for the AB, and 90% for the QUAD (**Fig. 2**). Only the ES showed a significant difference ($p=0.009$). The kinematic data showed significantly higher head-neck flexion ($p<0.001$) and torso-pelvis flexion ($p<0.001$) in the carrier compared to the playmat (**Fig. 3**). Head-neck flexion in the carrier ranged from 11.4° to 52.1° with a median flexion angle of 37.1°. Torso-pelvis flexion in the carrier ranged from 15.9° to 55.2° with a median flexion angle of 30.9°.

DISCUSSION: Comparing the carrier and playmat, significant differences were found in the body position of the infants and limited significant differences were found in muscle activation. This indicates that products sometimes change an infant's body position without changing muscle utilization to support the new posture. In addition, head-neck angles of just 15° to 30° can increase an infant's exhalation speed and decrease their lung capacity on inhale,[8] and flexion of 45° can significantly inhibit respiration in infants.[9] In our study, the head-neck angle of 37.1° upon normal placement in the infant carrier is concerning since additional flexion to hazardous levels will be easier due to the incline of the product and the tangential force of gravity compared to a flat surface. Furthermore, animal research has shown the importance of erector spinae muscles activity on the spinal development,[10,11] so curvature could be influenced with prolonged use of infant devices that limit the opportunity for infants to activate their muscles.

Torso-pelvis flexion relates to the product seat design and infants in our study exhibited 30.9° more torso-pelvis flexion compared to a flat surface while unconstrained. Our previous research on 22 infants showed significantly less lower extremity muscle activity in a carrier,[5] and they have also shown to negatively influence respiration in newborns compared to a flat lying condition, most likely due to an increase in intrabdominal pressure and compression of the diaphragm due to the flexed torso posture.[12] In addition to the increase in torso-pelvis flexion, we measured an increase in abdominal muscle activity, which may indicate that infants use their diaphragmatic muscles at a higher level to overcome breathing challenges related to the flexed posture.[13,14]

Offering infants a variety of body positions and movement opportunities throughout the day is beneficial to avoid gross motor milestone delays, head molding, shoulder retraction, and torticollis.[15,16] Caregivers should monitor time spent in these product types to decrease breathing risk as well as to prevent the risk of motor or musculoskeletal developmental delays. Future research should explore infant biomechanics during prolonged use of infant products.

SIGNIFICANCE/CLINICAL RELEVANCE: Infant biomechanics in common nursery products is a largely understudied area. This research quantified body posture and muscle activity of infants lying in car seats/carriers. Our results suggest that infants should avoid prolonged use of car seats/carriers outside of a motor vehicle to prevent respiratory-related hazards and musculoskeletal or motor developmental delays.

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ACKNOWLEDGEMENTS: This research was part of a larger study funded by the U.S. Consumer Product Safety Commission (CPSC, Commission) under contract number 61320620D00002/61320621F1014. It has not been reviewed or approved by, and may not necessarily reflect the views of, the Commission. Federal law requires that hand-held infant carriers comply with the Safety Standard for Hand-Held Infant Carriers, 16 CFR part 1225 (effective January 1, 2021), and with additional requirements, including those of the Consumer Product Safety Improvement Act of 2008 (CPSIA). Note that hand-held infant carriers that function as car seats are also regulated by the National Highway Transportation Safety Administration, under 49 C.F.R. § 571.213 Federal Motor Vehicle Safety Standard (FMVSS) No. 213.

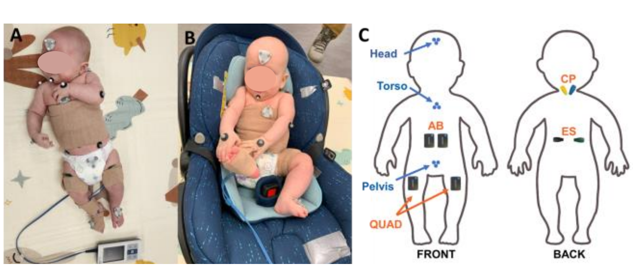

Figure 1: *Experimental setup on the (A) playmat and (B) infant carrier. (C) EMG and motion capture marker placement.*

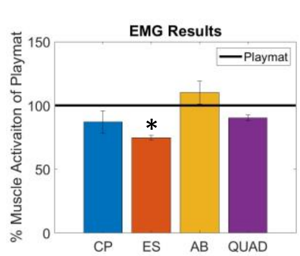

Figure 2: *Mean EMG data results *p<0.05 vs. playmat.*

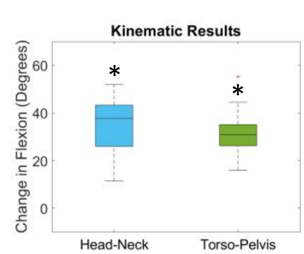

Figure 3: *Kinematic results *p<0.05 vs playmat*