PHYSICAL DEMANDS OF INSTALLING FORWARD FACING CHILD SAFETY SEATS INTO VEHICLES

POTVIN, JIM R.
Department of Kinesiology, University of Windsor
Windsor, Ontario, N9B 3P4, jpotvin@uwindsor.ca
BROWN, S.H.M.
GRONDIN, D.
GONZALEZ, M.
Department of Kinesiology, University of Windsor

The purpose of this study was to evaluate the biomechanical demands on parents as they install child safety systems into motor vehicles and as they place children in these systems. Muscle activation and joint rotation data were collected bilaterally from the trunk, shoulders and hands/wrist during installation and tethering of forward facing seats and child placement. It was concluded that these tasks can be very demanding and, thus, some individuals may not be capable of completing these tasks correctly putting the child at risk during a motor vehicle accident.
Key words: child safety, biomechanics, motor vehicle accident

LES EXIGENCES PHYSIQUES LIÉES À L'INSTALLATION D'UN SIÈGE D'AUTO POUR ENFANT DANS UNE AUTOMOBILE

La présente étude avait pour but d'évaluer les exigences biomécaniques exercées sur les parents au moment d'installer un siège d'auto pour enfant dans une automobile et au moment de placer l'enfant dans le siège. Les données liées à l'activation musculaire et la torsion articulaire ont été recueillies au niveau des deux côtés du tronc, des épaules, des mains et des poignets pendant l'installation et l'attachement du siège vers l'avant et le placement de l'enfant. La conclusion tirée révèle que ces tâches peuvent être très exigeantes et, par conséquent, certaines personnes pourraient être incapables d'effectuer ces tâches correctement, ce qui pourrait mettre la vie de l'enfant en danger lors d'un accident d'automobile.

Mots clés : siège d'auto pour enfant, biomécanique, accident d'automobile

INTRODUCTION

The leading cause of death for children over one year of age is motor vehicle accidents (Johnston, Rivara, & Soderberg, 1994). The improper use of child safety seats can cause serious injury to the child such as, head injuries, fractures, peripheral neuropathy, liver laceration, and cervical spine injuries (Lane, Liu, & Newlin, 2000). However, there is evidence to suggest that at least 80% of parents do not install child safety seats into automobiles in an optimal manner (Biagioli, 2002). This is obviously not because parents do not have the motivation to do so. Thus, it is possible that the cognitive and/or physical demands of installing these seats are too high to allow most to perform this important task correctly.

The purpose of this study was to evaluate the biomechanical demands on parents as they install child safety systems into motor vehicles and as they place children in, and remove children, from said systems.

METHODS

Subjects

Twenty-seven subjects volunteered to participate in this study. Of these, 13 were male and 14 female. Mean (standard deviation) anthropometric data was as follows for males: age 35.2(±13.8) years, height 181.9(±6.7) cm, mass 83.6(±11.3) kg and females; age 36.6(±14.2) years, height 164.3(±6.7) cm, mass 60.1(±8.3) kg. Subjects ranged from those without experience in installing child seats to parents and grandparents of children currently using such seats. All subjects were free from any recent low back, neck or upper limb pain or injury.

Experimental Set-up

The dimensions of a minivan, including an actual second row bench seat, front and overhead constraints, were mocked up in a laboratory setting. The minivan was mocked as having a single second row sliding door on the passenger side. Subjects were required to install a convertible (forward and rear facing) child safety seat in the middle seat of the second row bench. The seat was installed in the forward facing direction. The installation was divided into three steps: 1) lifting the child seat from the floor, placing it into the middle seat, threading and firmly securing the seat-belt through the child seat; 2) attaching and tightening the tether strap to a simulated rear dashboard; 3) lifting an 8.2 kg doll from approximately waist height, placing it into the child seat and securing the front belt clip between the dolls legs. Subjects returned to their original position outside of the van after each of the three steps. This entire process was completed three times for each subject. Subjects were given a demonstration as to the proper installation of the seat prior to data collection and were allowed to practice until they, along with the researchers, were satisfied with their ability to properly install the seat and secure the child.

Data Acquisition

Surface electromyography was collected from ten muscles bi-laterally. The muscles examined were as follows: lumbar erector spinae (LES), thoracic erector spinae (TES), anterior deltoid (Del), biceps brachii, and extensor carpi ulnaris (ECU). Disposable bipolar Ag/AgCl electrodes (Medi-trace, Graphic Controls, Gananoque, Ontario, Canada) were attached over the belly of each muscle. LES and TES electrode locations were at approximately L3 and T9 height respectively. Intra-electrode distance was 2.5 cm. Maximum voluntary contractions (MVCs) were obtained prior to data collection for the purposes of normalizing EMG data. EMG and goniometer data were collected with LabVIEW software (National Instruments, Austin, Tx., USA) using a PC compatible computer and converted by a 12-bit A/D card (National Instruments). EMG signals were amplified (1000 to 5000 times) prior to sampling, digitized at 300 Hz, full-wave rectified, and low-pass filtered using a second order Butterworth filter at a cut-off of 2 Hz. Signals were then normalized to MVC values.

A magnetic tracking device (3Space Fastrak, Polhemus, Colchester, Vermont) was used to collect kinematic angular (degrees) data of the spine and right and left shoulders. The electromagnetic transmitter cube was secured to the spine at the L4-L5 disc level. Sensors were attached over the sternum, and right and left anterior deltoids. For the deltoid locations, sensors were placed below the EMG electrodes. All sensors were zeroed prior to collection as subjects stood upright in the anatomical position. In addition, an electrogoniometer (Biometrics, Ladysmith, Vermont) was attached over the wrist to monitor wrist flexion/extension and ulnar/radial deviation (degrees). The right wrist was monitored for the first two installation sequences and the left wrist for the third installation. Goniometer data was collected at 300 Hz. Fastrak data was collected at 30 Hz in the Hyperterminal program (Windows 98, Microsoft, Redmond, Wa., USA). Video (30 Hz) of the installation was recorded from two cameras, one facing directly into the second row from outside the vehicle, and the other from above the simulated vehicle, facing down through a transparent roof.

At the conclusion of the collection period, subjects were asked to complete a subjective measurement tool that evaluated the physical and mental demands required in the installation of the current child restraint system. The tool consisted of a one-page 5-point Likert scale questionnaire.

Data and Statistical Analysis

Amplitude Probability Distribution Function (APDF) (Jonsson, 1982) analyses were conducted on the EMG, Fastrak and goniometer data. For the EMG data, the median and peak (99th percentile) values were calculated for each variable, for each condition with each subject. These values were averaged across subjects. For the trunk, shoulder and wrist rotations, probability values were calculated for each rotation in 5 degree increments. These curves were then averaged across subjects for each condition/variable combination. From these average curves, the 99th percentile value was calculated. Average scores were also calculated for each subjective rating.

RESULTS

EMG data

Figure 1 displays the average peak EMG values (% MVC) for each of the ten muscles monitored in each of the three portions of the overall installation task. In general, the tethering task was observed to result in the lowest demands for each muscle. The ECU muscle (representing the gripping force of the hands) was observed to have the highest activations for both the seat install (mean peak levels of 56.5±16.8% of maximum and 49.8±18.0 for the right and left respectively) and child placement tasks (51.4±19.6 right, 51.9±20.6 left). Other muscles observed to have average peak activations exceeding 40% of maximum were the right bicep (elbow flexor) while placing the child in the seat and installing the seat (43.9±20.0 and 44.0±20.3, respectively) and the anterior deltoid (used to flex the shoulder) during both the seat install and child placement (with average values ranging from 40.6 to 47.1% MVC).

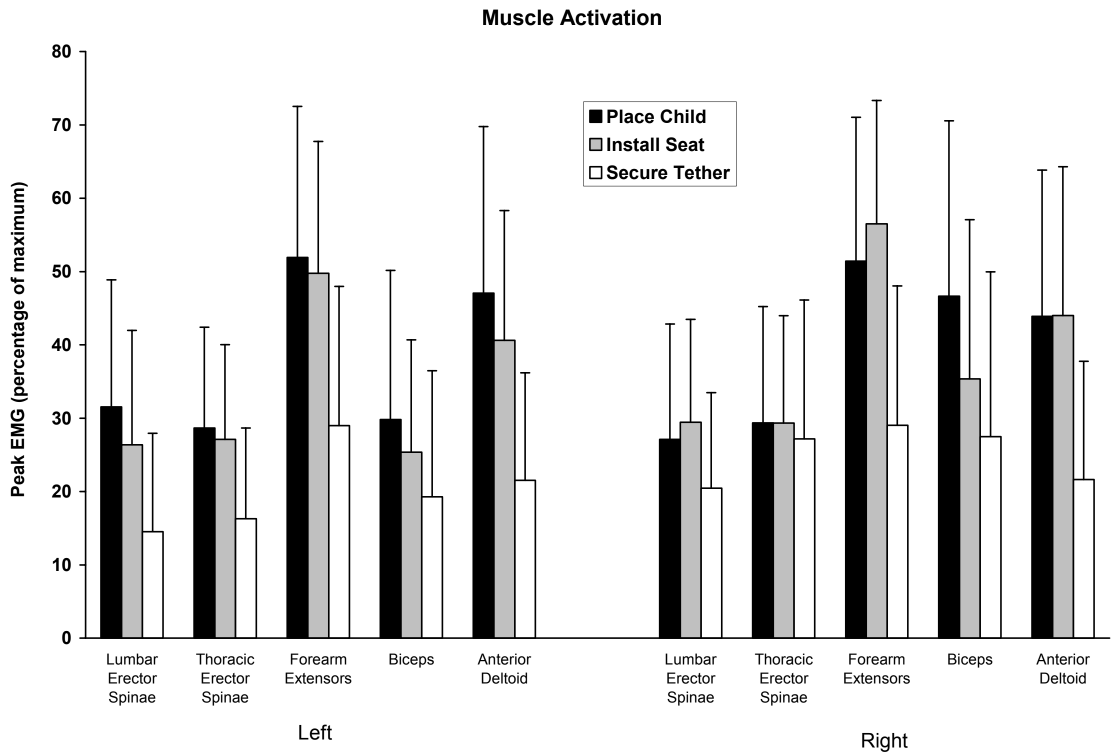

Figure 1: Average peak (99th percentile) EMG amplitudes for each muscle and condition. (n=27 for each mean, standard deviations are indicated).

Kinematic data

Figure 2 shows the average peak angular (degrees) postures, relative to the neutral posture, for the right and left shoulder, right and left wrist, and the spine. From a postural perspective, it was observed that the shoulders were forced into extreme postures for all three tasks. The largest peak abduction rotations were observed for the left shoulder during tethering and seat installation (14-150 deg). The largest peak shoulder flexions were observed for the tethering (180 deg) and child placement tasks (165 deg). Spine flexion rotations were observed to generally exceed 60 degrees for each of the three tasks, with the highest peaks being observed for the seat install tasks (70 degrees). In addition, these tasks also resulted in lateral bending beyond 40 degrees and spine twisting between 30-35 degrees.

Subjective ratings

Figure 3 displays the average subjective rating scores (complexity and physical demand) for each of the sub-tasks examined by the subjective measurement tool. Based on the subjective ratings, the three tasks requiring the greatest physical exertions were: 1) the insertion of the belt into the lock and tightening the strap, 2) adjusting the shoulder strap length for the child, 3) placing the child into the seat. The three tasks that were the most mentally complex were: 1) inserting the belt into the clip between the child’s legs, 2) threading the belt through the back of the safety seat, 3) adjusting the shoulder strap length for the child.

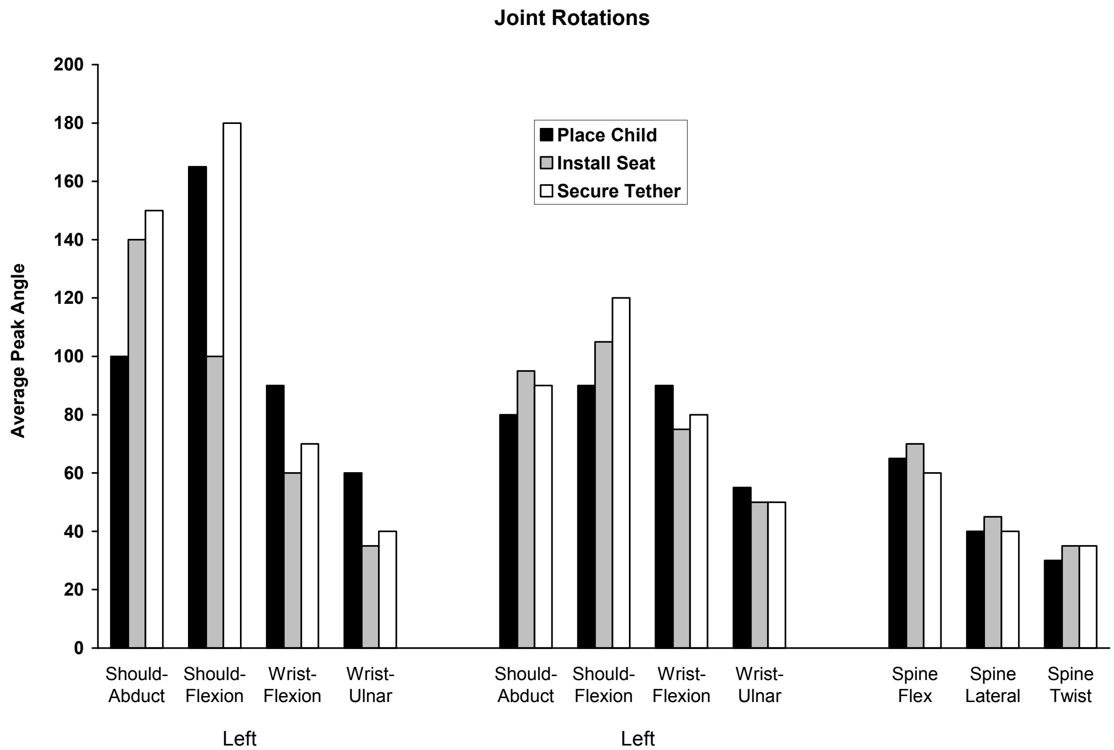

Figure 2: Peak (99th percentile) of average frequency distribution curves for the kinematic data for each joint axis and condition. (n=27 for each mean)

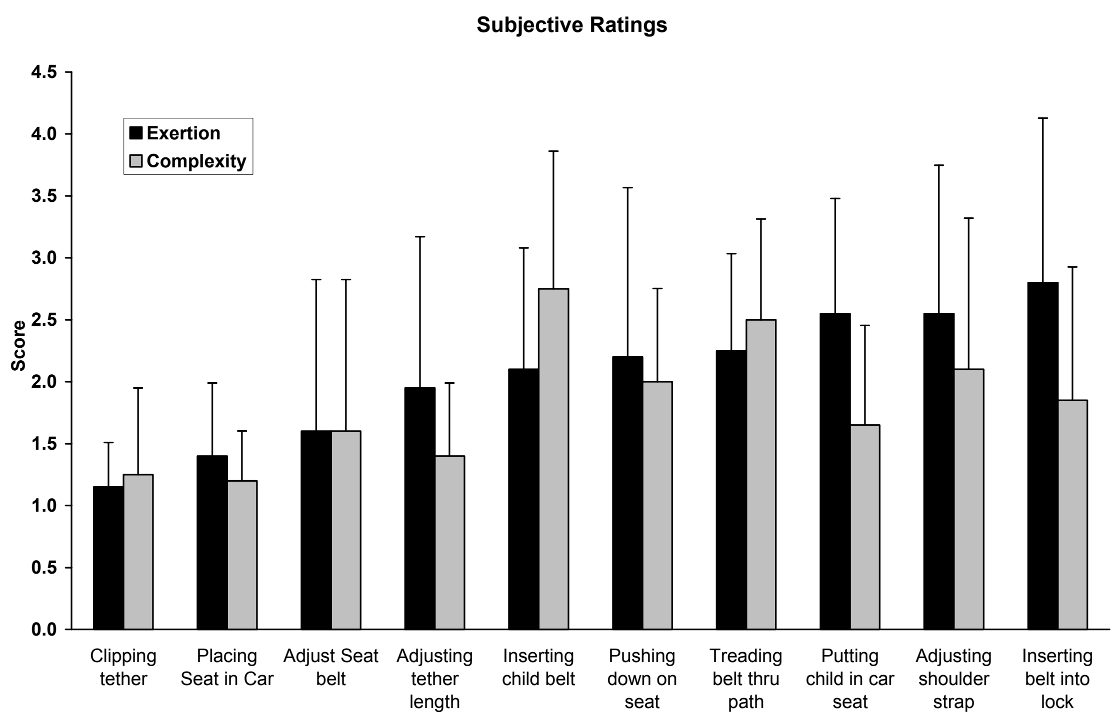

Figure 3: Average subjective rating score for exertion and cognitive complexity (n=27 for each mean, standard deviations are indicated).

DISCUSSION

The proper use of safety seats was observed to be very physically demanding. Many subjects were observed to require maximum efforts from the forearm and anterior shoulder muscles during the seat install and child placement tasks. The seat install was observed to require particularly high efforts and awkward postures during the routing of the seat belt, fastening of the belt and tightening of the strap. This is a critical aspect of proper seat installation and the high forces required, combined with the extreme postures may account for why so many seats are not installed correctly (Biagioli, 2002). In addition, the placement of the child in the seat appears to place high demands on the individual, especially for the hands, biceps and shoulders. Conversely, proper use of the tether does not appear to be limited by strength. These data need to be combined with cognitive studies to determine the causes of improper seat installation so that these issues can be overcome in the future.

This current study was designed to test as broad a range of factors as was possible with toddler seats in one study. The results indicate that installing the seat is the most demanding for the forearm/hand grip muscles, especially when attempts are made to engage the lock and pull the strap as tight as possible. Future research will focus more closely on this task as it has serious consequences for the performance of the seat during impact and appears to be one of the limiting factors in proper installation.

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