Forces and Postures During Child Climbing Activities

Technical Report

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16. Abstract

Many children are injured every year due to furniture and appliances tipping over and displacement of objects on furniture. Injuries are due to the furniture unit falling onto the child as well as falling objects supported by the furniture, particularly televisions. Clothing storage units, such as dressers, are a common type of furniture to tip over onto children. The current U.S. voluntary standard addressing the stability of clothing storage units, ASTM F2057-19, mandates a test procedure that involves applying a 50-lb weight at the edge of an opened drawer. No studies have previously assessed the forces that children exert when climbing under conditions similar to those associated with furniture tip overs. To address this need, a laboratory study was conducted with a convenience sample of 40 children ages 20 to 65 months from Southeast Michigan. Children were directed through a set of climbing behaviors on two instrumented bars (handles) to simulate a dresser, and with a simulated drawer and tabletop. Forces and moments gathered from load cells in the test apparatus were analyzed for 1173 behavior instances. The primary dependent measure was the tip-over moment calculated around a virtual fulcrum simulating the contact point between the floor and the front of the dresser. Five climbing behaviors — ascend, bounce, lean, yank, and leaning back while supported with one hand and one foot — were extracted from trials with a range of handle positions, and the maximum tip-over moment was computed from the handle force data. For the simulated drawer and table conditions, the moments at the time of ascent and descent were computed, as well as the peak moment during ascent.

Tip-over moments in all of the handle-trial behaviors exceeded the moment associated with body weight located one foot from the fulcrum. On average, the moments generated in the ascend, bounce, lean, and yank behaviors were equivalent to exerting 1.8, 2.7, 2.7, and 3.9 times body weight, respectively, at a distance of one foot from the fulcrum. The location of the child's center of mass (CM) was estimated in side-view images from the times of maximum moment. The results demonstrate that climbing, with vertically separated contacts for the hands and feet, enables children to exert tip-over moments that exceed those associated with the action of their body weight under their feet. Dynamic behaviors, such as stepping up, bouncing, or yanking can greatly increase the tip-over moment. In contrast, children climbing into or out of a simulated drawer tend to place their CM more inboard and thereby generate less tip-over moment than when climbing with vertically separated hand and foot placements.

These data provide the first available information on forces and moments associated with child climbing behavior and may be used to inform the design of furniture and the development of associated performance standards.

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ABSTRACT

Many children are injured every year due to furniture and appliances tipping over and displacement of objects on furniture. Injuries are due to the furniture unit falling onto the child as well as falling objects supported by the furniture, particularly televisions. Clothing storage units, such as dressers, are a common type of furniture to tip over onto children. The current U.S. voluntary standard addressing the stability of clothing storage units, ASTM F2057-19, mandates a test procedure that involves applying a 50-lb weight at the edge of an opened drawer. No studies have previously assessed the forces that children exert when climbing under conditions similar to those associated with furniture tip overs. To address this need, a laboratory study was conducted with a convenience sample of 40 children ages 20 to 65 months from Southeast Michigan. Children were directed through a set of climbing behaviors on two instrumented bars (handles) to simulate a dresser and with a simulated drawer and tabletop. Forces and moments gathered from load cells in the test apparatus were analyzed for 1173 behavior instances. The primary dependent measure was the tip-over moment (i.e., the torque that tends to tip the unit over) calculated around a virtual fulcrum simulating the contact point between the floor and the front of the dresser. Five climbing behaviors — ascend, bounce, lean, yank, and leaning back while supported with one hand and one foot — were extracted from trials with a range of handle positions, and the maximum tip-over moment was computed from the handle force data. For the simulated drawer and table conditions, the moments at the time of ascent and descent were computed, as well as the peak moment during ascent.

Tip-over moments in all of the handle-trial behaviors exceeded the moment associated with body weight located one foot from the fulcrum. On average, the moments generated in the ascend, bounce, lean, and yank behaviors were equivalent to exerting 1.8, 2.7, 2.7, and 3.9 times body weight, respectively, at a distance of one foot from the fulcrum. The location of the child's center of mass (CM) was estimated in side-view images from the times of maximum moment. The average estimated CM (ECM) location was outboard of the hands and feet in all handle configurations and behaviors, with the largest distances observed in the lean and yank conditions. The ECM locations were close to the edge of the simulated drawer and table in the associated trials, and the associated moments were equivalent to 0.8, 0.7, and 1.1 times body weight for the ascent, descent, and maximum moment points, respectively. The results demonstrate that climbing, with vertically separated contacts for the hands and feet, enables children to exert tip-over moments that exceed those associated with the action of their body weight under their feet. Dynamic behaviors, such as stepping up, bouncing, or yanking can greatly increase the tip-over moment. In contrast, children climbing into or out of a simulated drawer tend to place their CM more inboard and thereby generate less tip-over moment than when climbing with vertically separated hand and foot placements.

A comparison of the postures observed in the study with publicly available videos of children climbing dressers and other furniture suggests that the behaviors, particularly the ascent behaviors in both the handle and drawer trials, represent common movement patterns. Leaning and yanking are also observed in interactions with other household items, such as gates. These data provide the first available information on forces and moments associated with child

climbing behavior and may be used to inform the design of furniture and the development of associated performance standards.

INTRODUCTION

Many children are injured due to furniture and appliances tipping over and displacement of objects on furniture, particularly televisions. Gottesman et al. (2009) reviewed 18 years of hospital trauma data to characterize injuries to children due to tip overs. They documented an average of 14,700 injuries per year in the United States, about half of which were due to televisions falling on children. They noted that pulling and climbing on furniture accounted for more than 25% of the injuries. Wolf and Harding (2011) reviewed case reports of child fatalities due to furniture and television tip overs, documenting the role of climbing or other interactions in each case. Cusimano and Parker (2016) conducted a systematic literature review focused on falling televisions as a source of injury to children. Among the papers they surveyed, 19 of 29 identified climbing as the most significant cause of injury.

Recently, Suchy (2019) reported that the U.S. Consumer Product Safety Commission was aware of 459 fatalities among children, ranging in age from under 1 years of age to 14 years of age due to incidents of product instability or tip overs between 2000 and 2018. Data from hospital emergency departments indicates that, between 2016 and 2018, an estimated annual average of 12,500 children in the United States were treated for injuries due to product instability or tip-over. When children are injured, case reports suggest that these injury events commonly result from children climbing on or otherwise interacting physically with the product. Approximately 78% of estimated injuries to children occur in children six years old or younger; a majority of fatalities involve children between 1 and 3 ½ years old.

A majority of fatalities among children from tip overs involving only furniture are due to dressers, bureaus, and chests. ASTM F2057-19, Standard Safety Specification for Clothing Storage Units, defines a clothing storage unit is a "furniture item with drawers and/or hinged doors intended for the storage of clothing typical with bedroom furniture," such as chests, door chests and dressers. F2057 is a voluntary standard that has two stability-related requirements. The first evaluates whether an empty unit tips when all extension elements (drawers and doors) are open, with no additional weights or forces applied. The second is a static test with a weight to assess tip-over risk. Starting with an empty unit, a single drawer or door is opened to a specified position and a 50-lb weight is "gradually" placed on the edge. The unit meets the requirement if it does not tip over when all extension elements are tested individually. F2057 states that the 50-lb test weight is "equal to the 95th percentile five-year-old child." According to a nationally-representative study for the United States, published in 2016, the mean body weight of a five-year-old child (i.e., age 60 to 71 months) is 47 lb for boys and 45 lb for girls; the 95th-percentile body weight is 64 lb for boys and 61 lb for girls (Fryar et al. 2016).

Currently, minimal quantitative information is available on the forces exerted by children when performing climbing behaviors that may result in tip overs. Nose et al. (2018) reported on a research program aimed at characterizing child climbing activities, but forces were not measured. The test procedure in F2057 is based explicitly on a statically applied body weight, but information is needed on whether climbing behaviors could result in applied forces that exceed body weight, and whether a child could climb in such a way that the tip-over moment (that is, the torque that tends to tip the unit over) is greater than that produced by the child's body weight resting on the front edge of the drawer.

The objective of the current study was to examine the forces and postures associated with child climbing activities that might be among those associated with tip-over events. The study was not designed to obtain normative data for a population on the distribution of forces children can exert. Rather, the goal was to obtain data on the *possible* interactions that could be used to inform the design of furniture and related standards development.

To accomplish this objective, a convenience sample of 40 children, ages 20 to 65 months, from Southeast Michigan who were identified by their caregivers as showing interest in climbing in the household were recruited to participate in data collection sessions. The study had two major components. First, the children and their caregivers participated in a group discussion with the investigators that focused on the child's climbing behaviors. Second, a laboratory study was conducted to measure forces and postures exerted by the children in a range of climbing behaviors.

The children's size and body shape were quantified using traditional manual and three-dimensional anthropometry. The child participants were directed through a set of scripted behaviors on a laboratory apparatus, including climbing, leaning, and bouncing. Force and moment data were gathered from all interaction surfaces and video and three-dimensional point-cloud data were obtained from several angles.

The focus group data were analyzed to document the range of climbing behaviors the children exhibited, including the locations and types of furniture that they climbed. The data from the laboratory data collection were analyzed to quantify the maximum forces and tip-over moments generated by the children during the scripted behaviors across the various fixture configurations, along with the estimated center of mass locations at the time of peak force or moment. Data from a total of 1173 behavior instances were analyzed. The effects of the behavior type, fixture configuration, and child anthropometric characteristics were assessed.

METHODS

Reporting Units

The data in this study were gathered and calculations were performed using SI units: Newtons (N), meters (m), and Newton-meters (Nm). To improve interpretation for individuals more familiar with U.S. customary units, the plots and tables in this report show dimensions in inches and feet, force in pounds force (lb), and moments in pounds-feet (lb ft). These values were converted from the SI values using 4.45 N/lb, 0.0254 m/inch, and 1.355 Nm/lb-ft. Generally, the displayed unit was converted, rather than the preceding values. For example, moment calculations were performed using N and m, then converted to lb-ft. Calculations were performed at the available data resolution, typically 10 digits. The displayed values are rounded to three significant digits, which corresponds approximately to measurement precision for forces and moments.

Relevant Furniture Dimensions

CPSC staff provided dimension data from over 180 clothing storage units. Of particular interest for the current study was the height of the upper front edge of the lowest drawer relative to the floor, since this would be a likely point of force application for a climbing child. The drawer extension, i.e., how far the drawer could be pulled out before hitting a stop, was also a consideration, since this affects the tip-over moment a child can generate. In general, when vertical forces are applied at the upper edge of the drawer front, larger values for extension create greater tip-over moments. Similarly, rearward forces exerted at a greater height are associated with larger tip-over moments. Table 1 shows summary data for these two values. Based on this analysis, the values for 16 inches height and 12 inches for extension were used in the analysis to estimate the potential effects of the measured forces and moments on tip-over moment. The moment calculations were performed using the SI equivalents of 406 and 305 mm, respectively, and the results converted to U.S. customary units for reporting. These calculations are explained in detail below and the effects of choosing different values for these dimensions are quantified.

Table 1
Summary Statistics for the Lowest Drawer of Clothing Storage Units (inches)

Dimension	N	Mean	SD	10^{th}%ile	50^{th}%ile	90^{th}%ile
Height	175	13.5	2.4	11.1	13.4	16.1
Extension	182	10	1.6	8.4	9.8	11.9

Laboratory Apparatus

Laboratory Space

The test fixtures and laboratory space used in this study were purpose-built for this and related studies with children. Figure 1 shows a schematic of the laboratory space, and Figure 2 shows photos of the space while testing was in progress. A column with linear tracks on four sides was located in the center of the laboratory. The column was bolted to the cement floor and braced by beams that extended to the walls near the ceiling (Figure 3). Reconfigurable fixtures were mounted on bearings attached to the linear tracks on the sides of the column. A force plate was bolted to a concrete pad on the floor in front of the column, and a raised platform floor was built so that the floor of the testing area was level with the top of the force plate.

The raised floor area was flanked on two sides by half-walls with doors. A transparent wall on the side of the laboratory where participants entered created a space where participants and their families could sit and see all of the testing activities. An opaque wall on the opposite side of the laboratory separated the raised testing area from the data acquisition system and test fixtures not being used during a trial.

Edges and surfaces accessible to children were covered or padded. The floor under and around the test fixtures was padded with large pieces of ArmaSport ALC (Armacell) foam, a polyvinyl chloride/ acrylonitrile butadiene rubber blend. The manufacturer states that it has a 25% compression resistance at 4.0-6.0 psi, a 50% compression set at 25% of maximum, and density of 6.0-8.5 lb/ft^3 (ASTM D 1056). It has a minimum tensile strength of 90 psi and elongation of 125% minimum (ASTM D 412). The padding on top of the floor force plate was cut so that it did not touch the surrounding floor or padding. Padding that covered the other load cells was constructed so that it would not rest on the load cell.

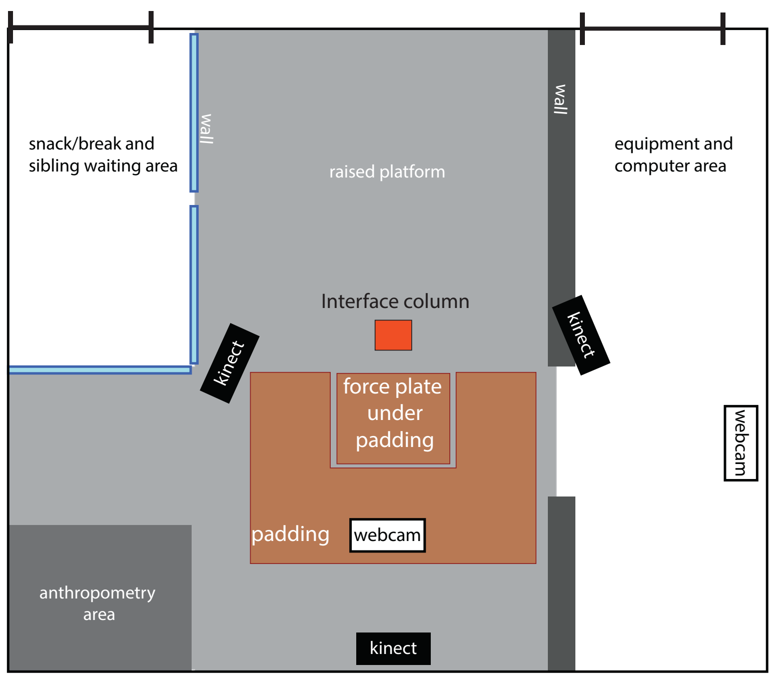


Figure 1. Floor plan of laboratory where climbing study was performed showing testing area in grey and waiting and storage areas in white.

Figure 2. Photos show the laboratory space in use. The photos on the top shows a child approaching a representation of a dresser front with instrumented handles and an investigator giving encouragement, along with a side view of a child on the apparatus. The photos on the bottom show the waiting/break area for children (bottom left), a child participant climbing down from a table condition in the center of the lab while a parent crouches alongside (bottom middle), and an investigator running the data acquisition system while a child participant sits in the open drawer (bottom right).

Figure 3. The photo on the left shows the beams bracing the center column. The photo on the right shows the data collection equipment (Kinect Azure and webcam) attached to the beams.

Handle (Bar) Fixtures

A laboratory apparatus was constructed to provide children with the opportunity to perform a set of scripted climbing behaviors. The apparatus was intended to facilitate the climbing behaviors rather than being typical of any type of furniture. Figure 4 shows a child on the apparatus.

Figure 4. Child on the climbing apparatus. The positions of the two bars (red) could be adjusted vertically and horizontally.

A set of two bars that could be moved and then locked into different horizontal and vertical positions was used to simulate a climbing surface. Figure 5 shows both bars (handles). The handles were designed to provide advantageous grip surfaces so that the children's force exertions were not limited by discomfort due to sharp edges. The upper bar that the children grabbed with their hands was a 460-mm-long rod with a diameter 19 mm mounted to a load cell at the middle of its length. The diameter was chosen as a comfortable diameter for children to grip based on pilot testing. The lower bar, which supported the child's feet during most behaviors, was 610 mm long with a diameter of 25.2 mm. The lower bar was mounted along its length to a flat piece of angled aluminum that was attached to a load cell at middle of the bar length. The purpose of the flat metal adjacent to the bar was to keep the child from falling to the floor if the child's foot slipped forward. The lower bar was round so that the interface between the child's foot and the surface was the same regardless of the angle of the child's foot while on the bar.

The bars were covered in a Durabak brand polyurethane marine coating. This material provided a smooth surface with high friction that could be sanitized easily. The color red was chosen to contrast the colors in the lab, make the bar visually appealing, and enhance oral instruction to the children.

The bars and load cells were attached to movable arms constructed from two pieces of extruded aluminum. The arms straddled the central column and traveled fore-aft along two linear bearings. The arms could also be moved vertically with two additional linear bearings on the column. Each of the four bearings had two locks used to keep the bars securely in place once positioned.

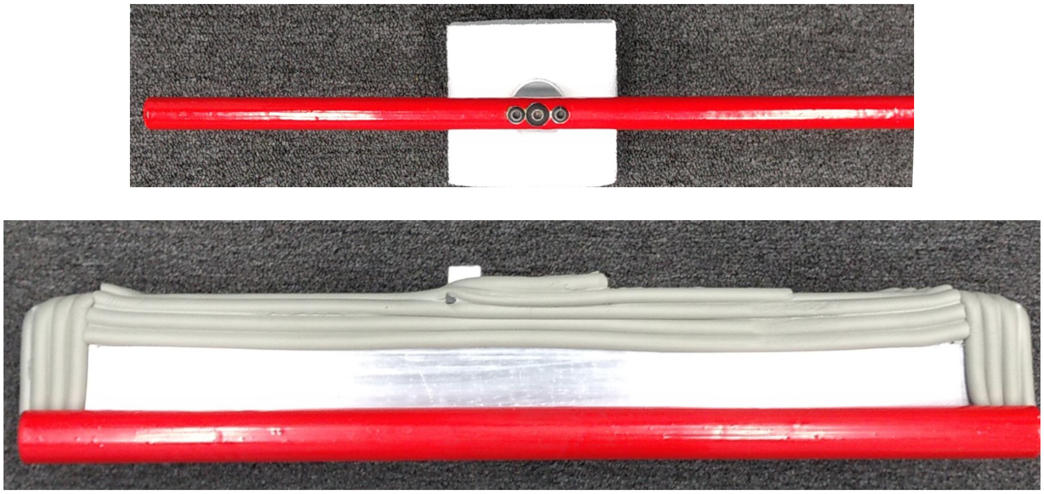


Figure 5. Interaction bars used in the climbing trials. The children grasped the thinner upper bar (top) with their hands and interacted with the thicker lower bar with their feet. The edge of the flat aluminum safety surface on the lower bar was covered with foam padding.

Drawer and Table

In addition to the bars used for climbing behaviors, a separate fixture was constructed to simulate a drawer and table-top (see Figure 6). The drawer was made in two parts. The main part of the drawer was an aluminum box, bolted to a six-axis force plate. The box was open in the front and at the top and had transparent plexiglass windows on two sides. The inside of the box was 24 inches wide by 16 inches deep by 8 inches high. The inside bottom surface was padded with the same material as the floor, decreasing the interior height to 6.75 inches. The front surface of the drawer was a separate piece of aluminum 24 inches wide by 12 inches high. This piece did not touch the main part of the drawer and was supported separately by a six-axis load cell. The top edges of both parts of the drawer were covered in lengths of foam padding for protection. Figure 7 shows the two parts of the drawer. The box and its force plate were bolted to the top of the support arm used for the handle trials, and the front of the drawer with its load cell were attached to the front of the support arm. As the box was being set to the height needed for a trial, wood supports were placed under the arm so that the weight of the box would be supported by the floor instead of the central column and the bearings on linear tracks were locked, providing greater rigidity.

A vertical surface extending the width of the drawer was placed behind the drawer, extending from a couple of millimeters above the top edge of the back of the drawer to a height well above the child when in the box (Figure 8). This surface was also supported by the central column and instrumented with a 6-axis load cell. However, interaction with the back surface was infrequent and the data were not analyzed.

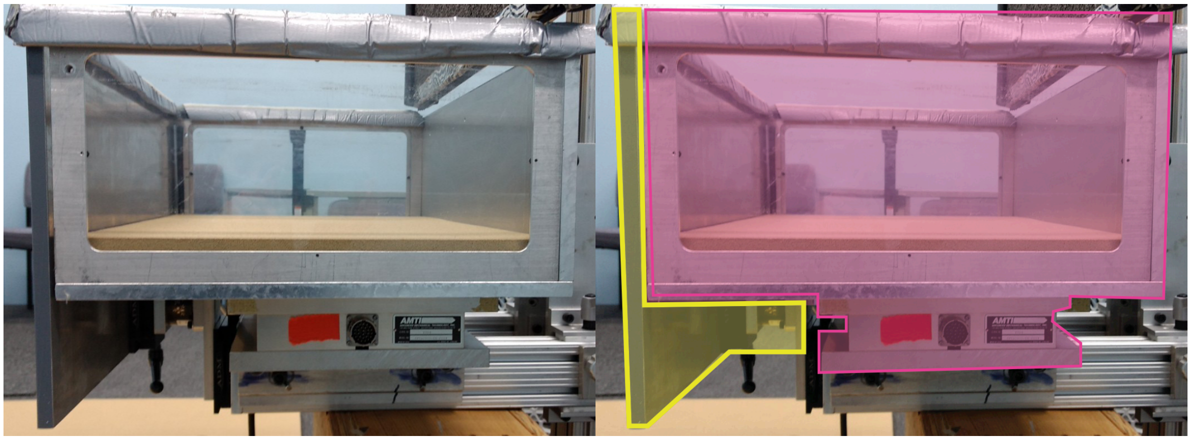


Figure 6. The image on the left shows a closer view of the force instrumentation for the drawer conditions. The front side of the drawer was mounted separately from the rest of the box. The image on the right highlights the separate pieces.

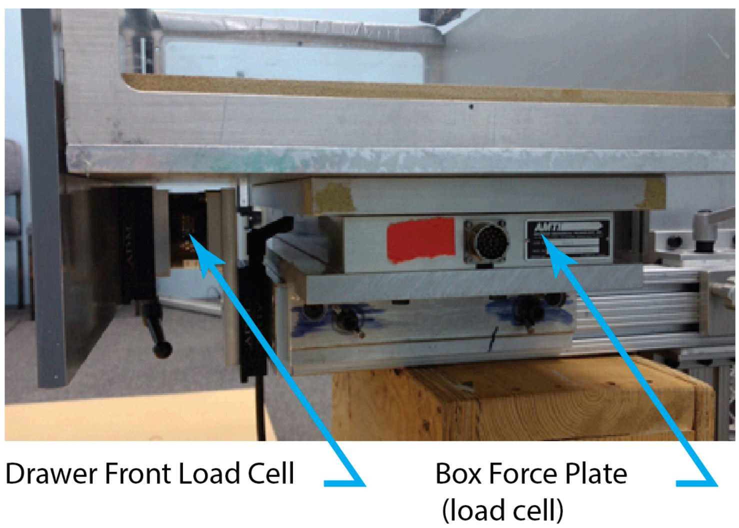


Figure 7. Close-up view of the underside of the drawer fixture, showing the two load cells that were used to measure forces and moments on the drawer front and the main part of the drawer (box).

A flat "table" was created by bolting a 28-x-16-inch wooden board to the back and sides of the drawer box. This set up was intended to simulate a tabletop or the top of a dresser or other furniture unit. The forces the child exerted on the table were only measured by the force plate under the box. The front of the drawer was still in place, and the load cell behind it measured forces the child applied to the front surface only. Because the top surface of the drawer front was covered by the tabletop, forces on the drawer front in this condition were limited to being predominantly horizontal. Figure 8 shows a table condition. The vertical surface behind the table was raised a few millimeters above the table to avoid force transfer between the components.

Figure 8. Photos of the table condition from two perspectives, showing the flat wood tabletop added to the box frame.

Instrumentation

The force plate under the main part of the drawer was an AMTI model BP250500-6-2000, and the force plate under the floor was an AMTI model OR6-7-1000. The load cells used for the front of the drawer, the vertical surface behind the drawer, and both handles were Denton model 3300. Data from the force plates and load cells were acquired using custom software interfacing with a National Instruments CompactDAQ with NI-9237 modules. Data were recorded at 2000 Hz with the forces in N and the moments in Nm. Force and moment data were initially low-pass filtered for anti-aliasing at 900 Hz. A 200 Hz, 4^{th}-order, phaseless low-pass filter was applied prior to analysis. As noted above, the calculated values were converted to lb and lb ft for tables and figures in this report.

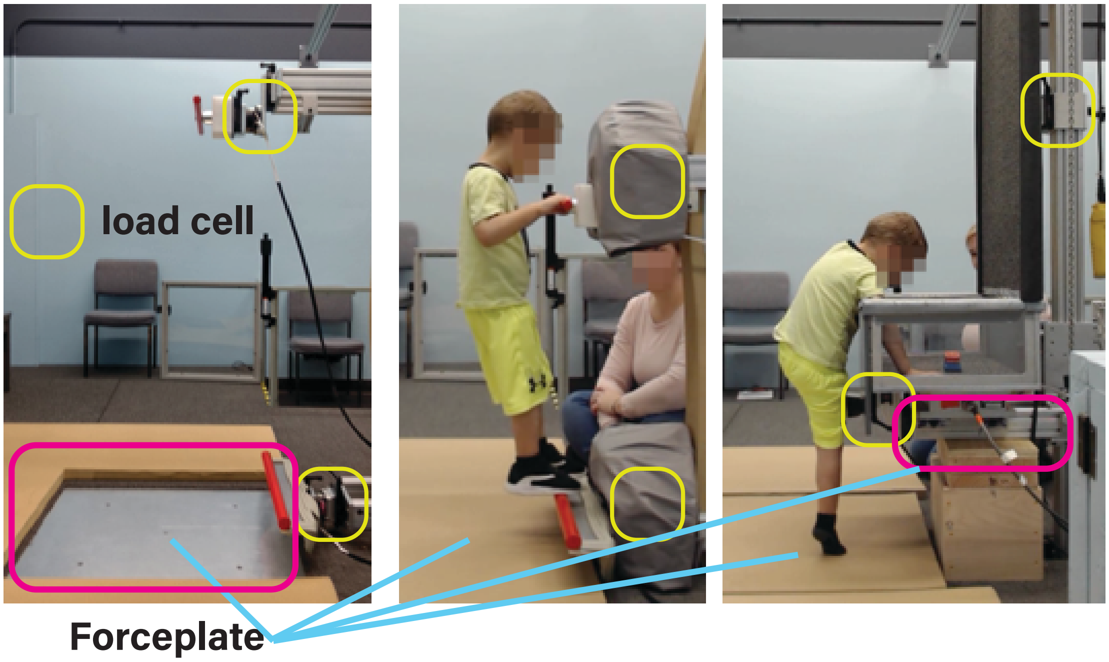


Figure 9. The image on the left shows the laboratory set up for a handle condition with the padding removed to show the force instrumentation behind the bars and on the floor. The image in the center shows the same type of condition but with the instrumentation covered with padding. The image on the right shows the set up for the drawer condition with the force instrumentation for the drawer, the drawer front, and the front surface of the furniture behind the drawer.

Figure 10. The handles were mounted on the 6-axis load cells via a quick release locking system. The photo shows the handle with the load cell behind it.

Video and Posture Measurement

Two Logitech C920 cameras were used to record the participants' movements. The cameras collected 640-x-480-pixel images at a rate of 15 Hz. Figure 11 shows the fields of view for the cameras. One camera was mounted on an overhead track and was moved between trials to get the best field of view possible for the trial. The other camera was mounted on the wall to the right of the test fixture and was not moved during testing.

The side-view camera was calibrated for making quantitative measurements using a checkered grid (Figure 12). Images were recorded with the grid at the far side of the drawer, at the middle of the fixture, and at the near side (closest to the camera). The images were digitized to establish calibration factors relating the image dimensions (pixels) to physical dimensions in the laboratory space. The calibration value for the middle position was used for the calculations in this report, with the far and near calibrations serving as approximate error bounds for these measurements. Based on the calibration data, the measurements from the webcam images are estimated to be accurate ±15 percent. On average, distances between landmarks are probably slightly overestimated, since the measured points on the right side of the child's body usually lay somewhat closer to the camera than the center of the fixture.

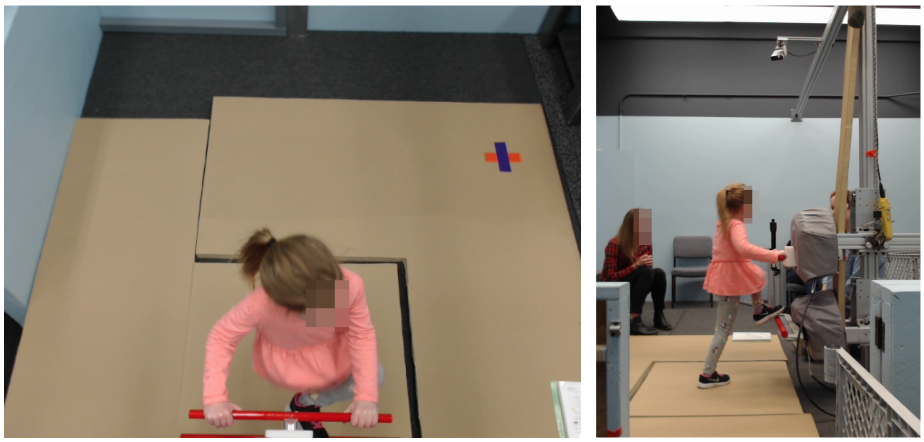


Figure 11. Example of camera fields of view: top (left) and side (right).

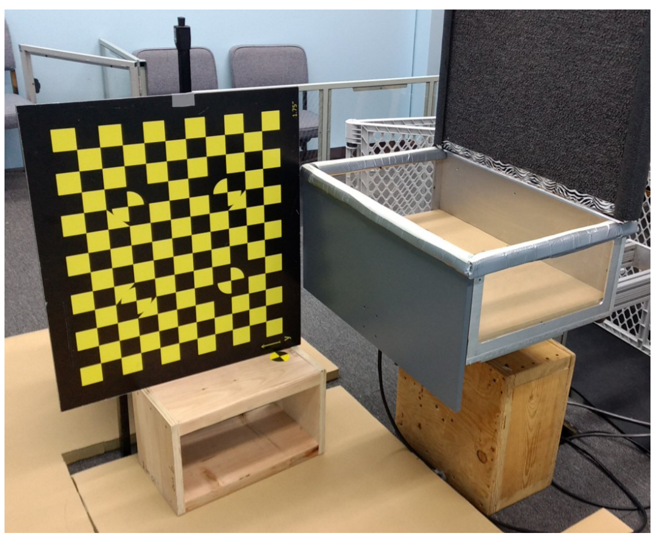


Figure 12. Camera calibration grid set up for the side-view webcam.

3D Posture Measurement

A 3D human motion tracking system based on Microsoft Azure Kinect sensors was used to capture the 3D posture of the participants (Figure 13). Placement of the sensors was constrained by the test fixtures and possible occlusion by the additional people in the room. Three sensors were placed in a triangular shape above the test fixture area. Two were located on either side of and to the front of the participant, and the third was placed directly behind the participant. Figure 14 shows an image from the 2D RGB camera on each Kinect sensor. The data from the Kinect sensors were not analyzed for this report.

Figure 13. One of the Azure Kinect sensors mounted in the laboratory.

Figure 14. Examples of the RGB camera fields of view from the three Azure Kinects during data collection.

Study Population

Recruitment

Caregivers of 189 children in the desired age range responded to an online advertisement on the University of Michigan portal for participation in research studies. In a phone interview, caregivers were asked the following questions:

> How old is your child? [require 18 to 71 months]
>
> What is your child's gender? [recorded to consider girl/boy balance]
>
> Does your child have normal physical development? [require yes]
>
> Can he/she participate in normal physical activities, such as running and playing on playground equipment? [require yes]
>
> Has your child shown an interest in climbing on a household item (not on a playground)? [require yes]
>
> In this study, we will ask your child to push and pull very hard with his/her hands and feet, and climb up on laboratory equipment above a padded floor. Does that sound like something your child would be able to do? [require yes]
>
> Does he/she currently have any illness or injury that would make it difficult for your child to participate? [require no]
>
> Is your child able to follow spoken instructions in English at a level appropriate for his/her age? [require yes]
>
> Is it OK for us to record video of your child? [require yes]

Equal numbers of boys and girls were selected from among those who answered these questions in the manner required. Consequently, all participants were children whose caregivers indicated that they have "shown an interest in climbing a household item" and all had typical motor development. From among those eligible, children were chosen to fill the sex/age bins in Table 2. Availability for open test times was also a consideration in choosing participants.

Forty children participated in this study. Table 2 shows the age bins targeted and the age distribution of the participating children. Because some of the children were not able to complete all of the testing conditions, more participants than originally planned were recruited to ensure the number of completed trials across conditions was reasonable.

Table 2
Participant Age Distribution

Age Range	Original Target Number	Number of Female Participants	Number of Male Participants	Total Participants
18 – 23 months	4	2	4	6
24 – 47 months	12	11	10	21
48 – 71 months	8	7	6	13
Total	24	20	20	40

Standard Anthropometry

Standard anthropometric dimensions, including stature, body weight, and linear breadths and depths were gathered from each participant to characterize the overall body size and shape. Table 3 lists the anthropometric measures collected, and Table 4 lists a summary of these measures for the children tested. Appendix A explains the anthropometric methods and Appendix B lists all of the values. Figure 15 shows a plot of stature and body weight, demonstrating the range of both variables.

Table 3
List of Standard Anthropometric Measures

Weight	Erect Sitting Height
Stature	Hip Breadth
Axilla Height	Buttock-Popliteal Length
Omphalion Height	Buttock-Knee Length
Max Step Height	Bi-acromial Breadth
Upward Grip Reach	Waist Circumference at Omphalion Height
Span	

Table 4
Summary of Participant Anthropometry (US Customary Units)

Measurement	Minimum	Maximum	Mean	Median	SD
Age (mo)	20	65	40	38	13
BMI (kg/m^2)	13.7	20.7	16.7	16.4	1.6
Weight (lb)	22.7	50.1	34.4	34.2	6.2
Stature (in)	29.3	44.1	37.9	37.5	3.7
Axilla Height (in)	21.5	31.7	27.0	27.1	3.0
Omphalion Height (in)	15.4	25.3	20.9	20.3	2.8
Upward Grip Reach (in)	32.4	52.0	43.1	42.1	4.7
Max Step Height (in)	6.9	15.8	10.5	10.3	2.4
Waist Circumference at Omphalion (in)	18.0	25.7	20.7	20.5	1.3
Erect Sitting Height (in)	18.4	25.6	21.9	21.6	1.7
Hip Breadth (in)	6.7	10.6	8.0	8.0	0.8
Buttock-Popliteal Length (in)	7.4	13.8	9.9	9.3	1.4
Buttock-Knee Length (in)	7.2	14.3	11.9	11.8	1.6
Biacromial Breadth (in)	7.5	10.7	8.8	8.7	0.7
Reach Span (in)	28.1	43.5	36.6	36.6	4.1

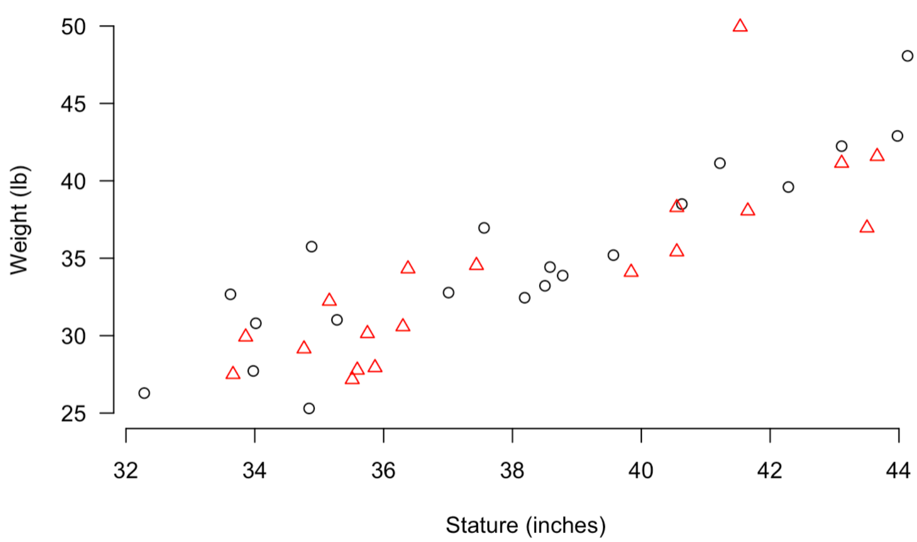


Figure 15. Participant weight versus stature for boys (circles) and girls (triangles).

Three-Dimensional Anthropometry

In addition to standard anthropometric data, body shape and surface contours were recorded using a Vitronic Vitus XXL full-body laser scanner and Scanworx software by HumanSolutions.

The VITUS XXL records hundreds of thousands of data points on the surface of the body in about 12 seconds by sweeping four lasers vertically. The two cameras on each of the four scanning heads pick up the laser light contour projected on the participant and translate the images into accurate three-dimensional data. The participants were scanned in a standing and an unsupported seated posture.

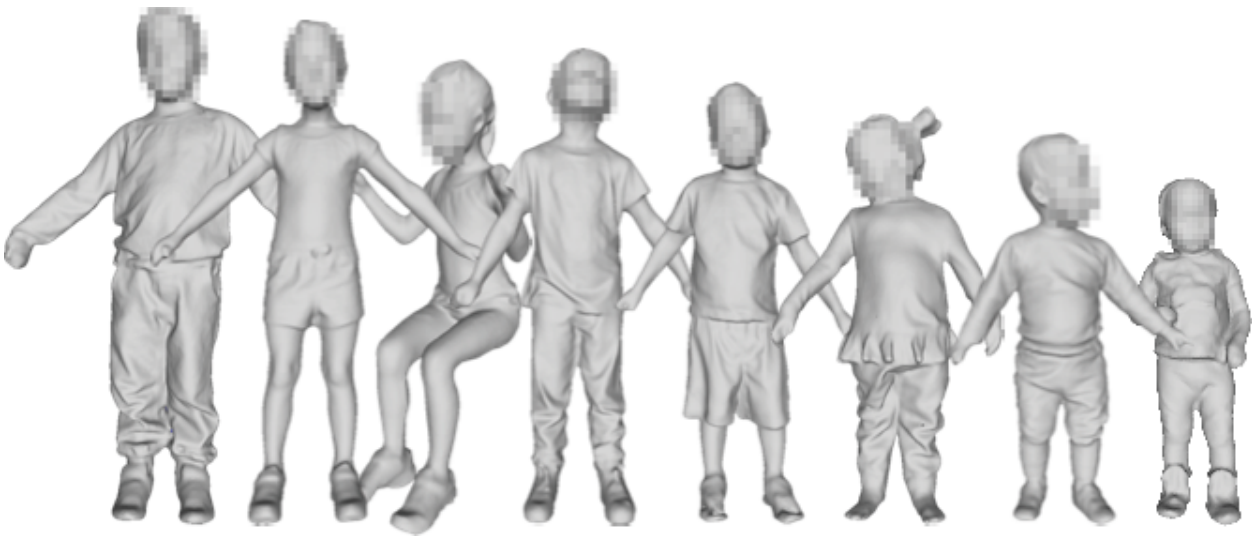


Figure 16. Examples of child 3D scans, from left to right: 5YO (1117 mm), 5YO standing and seated (1105 mm), 5YO (1021 mm), 2YO (970 mm), 2YO (904 mm), 21MO (864 mm), and 21MO (743 mm)

Focus-Group Questions

The participant and caregiver were asked questions during the testing session about the participant's typical climbing behaviors at home and in other settings (Appendix C). The questionnaire was administered orally, and participants were encouraged to expand upon any answers given. Typically, the investigators began the questions early in the testing session and returned to them throughout the session as breaks were needed for the child.

Child Activities and Instructions

The study protocol was approved by an institutional review board for human-subject research at the University of Michigan (HUM00158177). Caregivers were required to stay with their children at all times during the testing session, which was limited to 2 hours. Children and caregivers were offered breaks throughout the testing session and caregivers were encouraged to request breaks if they thought their child needed them.

Prior to arrival, caregivers were requested to dress their children in shorts or leggings, a tight shirt, and shoes with firm, grippy soles (tennis shoes given as a good choice). Upon arrival, an investigator read an introductory script to the caregiver and child. After obtaining written consent from the caregiver and oral consent from the child, participants were asked to remove their shoes and anthropometrical measurements were collected. The introduction script and other scripted instructions are in Appendix D.

The order of climbing trials was drawer, table, and handles. After the drawer and table trials, the participant and caregiver were taken to another laboratory for the scanning portion of testing. While the participant was in the scanning laboratory, an investigator exchanged the drawer/table fixture for the handles so that they would be ready when the participant returned. When all trials were completed, the caregivers were paid, and the child was offered a choice of a small toy from a prize chest. Caregivers were also given a tip-over safety handout (Appendix F).

Drawer and Table Test Conditions

Instructions were given to the participant and caretaker while an investigator set up the apparatus relative to the participant's anthropometric measurements. Participants were asked to climb into the drawer, sit down for a moment, and then climb out (see Appendix D for the specific instructions to the children). This task was performed at two or three heights. The first time the child climbed into the drawer, the top edge was set to the height of the child's omphalion (navel). In pilot testing, all children were physically capable of climbing into a drawer set to this height. Having the child easily succeed and receive praise for the first testing condition was important in setting the tone of testing and making the experience enjoyable for the child. For the next trial the drawer was set to a higher position. If the child easily climbed into the drawer set to omphalion height, the drawer was raised to the height of the child's axilla (armpit). If the child had some difficulty climbing into the drawer at omphalion height, the drawer was raised to only halfway between the child's omphalion and axilla. If the child could climb in at this height, the drawer would then be raised to the height of the child's axilla. If a child went from omphalion height directly to axilla height, but found axilla height too difficult, the drawer was then lowered to the location midway between omphalion and axilla. Figure 17 illustrates this process of setting the drawer heights.

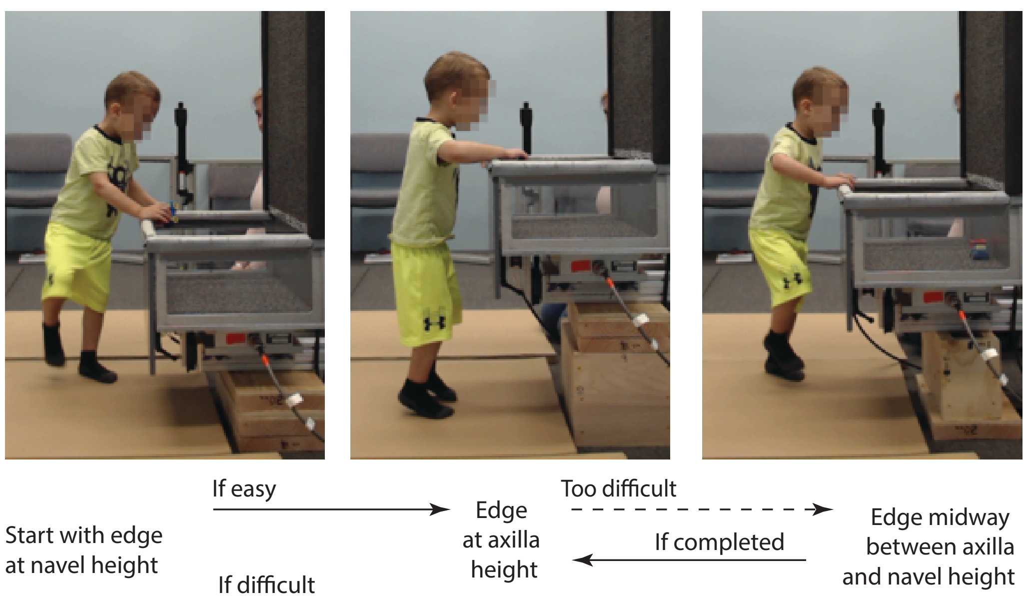


Figure 17. Illustrated flow chart showing how the different heights of the drawer were presented to the participant.

After the drawer trials, the drawer was left at the highest position the child was able to successfully climb into and a solid wood board was placed on top of the drawer to simulate a tabletop or the top of a dresser or other furniture unit. The board was rigidly attached to the sides and back of the drawer so that it only loaded on the force plate under the bottom of the drawer (see Figure 8). Participants were placed on top of the fixture and asked to climb down to the front. If the child did not land on the floor force plate, the trial was repeated if possible. Figure 18 shows frames from a table trial.

Figure 18. Photos of a child placed on the table by her caregiver and then climbing down on her own.

Handle Test Conditions

The locations of the upper and lower bars in the handle trials were reconfigured relative to the size of the child to achieve a range of child interactions with the apparatus listed in Table 5. The lower bar the child stepped up on was set to two positions. The “high” position was the height of the child’s maximum step height above the padded floor. The mean value of maximum step height was 10.5 (sd 2.4) inches (see Appendix B). The low height of 4.7 inches was chosen to be as low as possible for safety while also allowing the children’s feet to interact with the bar from various angles without contacting the floor. Because the spacing between the bars was expected to alter posture and force generation, the vertical and horizontal position of the upper bar were varied based on the child’s upward grip reach height. The height of the upper bar was set to three different positions relative to the padded floor surface: 100%, 75% and 50% of the child’s upward grip reach. These are referred to as “high,” “mid,” and “low,” respectively, in Table 5. The horizontal position of the upper bar was set so that it was either “aligned” with the lower bar, or “offset” from the lower bar to be closer to the child approaching the handles. The offset was 20% of the upward grip reach height.

Table 5
Handle Trial Test Conditions and Actions Requested

	Bar Locations			Behaviors Requested					
Order	Lower Bar Height	Upper Bar Vertical Height	Upper Bar Horizontal Position	Climb Up (Ascent)	Bounce	Lean Back & Yank	1 hand & 1 foot	Other	Climb Down (Descent)
1	High	Mid	Aligned	X					X
2	High	High	Aligned	X					X
3	High	Low	Aligned	X					X
4	Low	Mid	Aligned	X	X	X	X		X
5	Low	Mid	Offset	X	X	X			X
6	Low	Mid	Offset					Hop up	
7	Low	Low	Offset					Hop up	
8	Low	Low	Offset	X	X	X			X
9	Low	Low	Aligned	X	X	X	X		X
10	Low	High	Aligned	X	X	X	X		X
11	Low	High	Offset	X	X	X			X
12	Low	High	Offset					Hop up	
13	Low	High	Offset					Hang	

For each configuration of the handles, the participants were asked to perform a set of actions. The actions usually started with climbing up (ascent), standing with both feet and hands on the bars, and then climbing down (descent). If the child did something other than a standard climbing motion, for example jumping up or falling down, the trial was repeated requesting the child to also perform a climbing action. Both standard and non-standard climbing actions were recorded, and the child was praised following their attempts. In conditions where the lower bar was set to the higher position as shown in Figure 19, the upper bar was always aligned horizontally with the lower bar and only the climbing up, standing, and then climbing down actions were requested. The higher bar presented a greater risk of injury if the child fell, therefore more complex actions were only requested when the lower bar height was set to the low height.

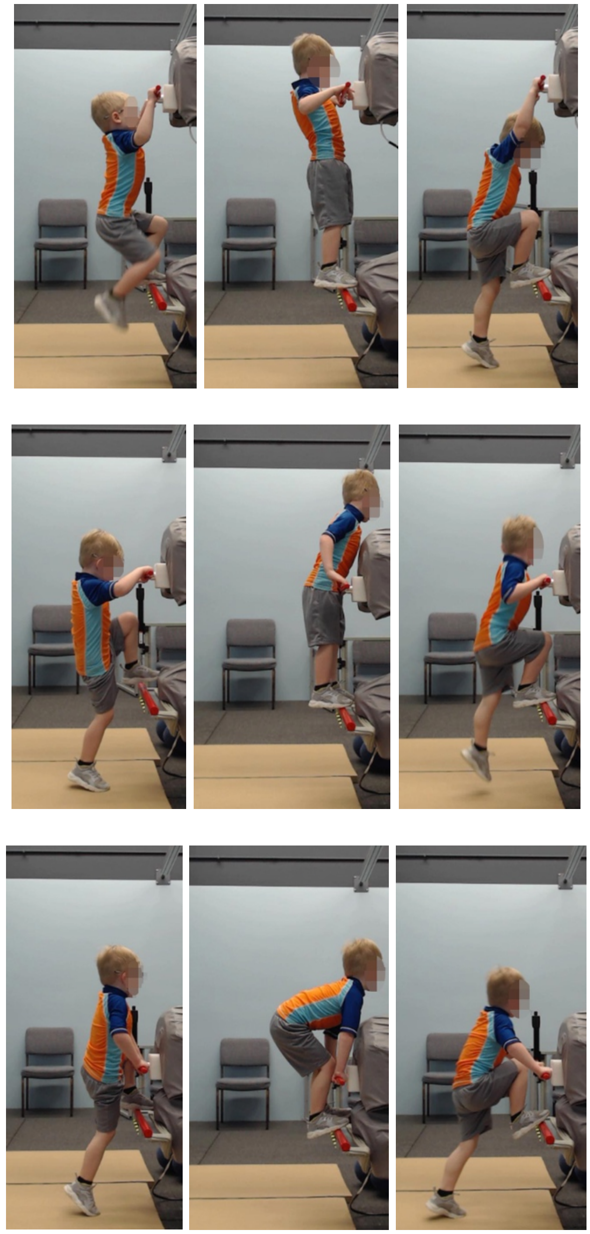


Figure 19. This series of photos show a child climbing up and down with the lower bar set to "high" maximum step height position and the upper bar set to the "high," "mid," and "low" bar heights (top to bottom) which were 100%, 75% and 50% of upward grip reach height, respectively.

For the configuration with the lower bar at the low height, the child was asked to climb up and then 1) bounce vigorously without leaving the bar, 2) lean back as far as they could while keeping both hands and feet on the bars, 3) stay in this leaned-back position and then pull on the bar as hard as they could and 4) to take one hand and foot (ipsilateral) off the bars and then lean as far away from the bars as possible. These actions are shown in Figures 20-24. The one-hand and one-foot action was not possible for most children to do without falling when the upper bar was low and offset, therefore it was not requested in that handle configuration. Figures 25 and 26 show two additional actions requested in a subset of handle configurations. A request to "hop-up" meant the child would hold the upper bar and try to jump from the floor to a position where their arms were straight and their hips were in front of the upper bar, an action similar to hoisting oneself out of a swimming pool. This was only requested when the upper bar was offset from the lower bar, so that the child could land on the padded floor instead of a metal bar. A request to "hang" was only made when the upper bar was at the high, offset position. The child would be asked to hold onto the upper bar, lift their feet off the floor by bending their knees, hang still for a few seconds, and then straighten their legs to return to the floor.

The words used to request the child to perform these actions were kept very simple. Scripts of these instructions are in Appendix D. Instructions usually were kept to three-word sentences, for example, "Please climb up" or "Hands go here" and then augmented by hand signals such as pointing to the upper bar. The illustrations in Figures 20-26 were printed on a laminated sheet and shown to the child and caregiver as needed to help in comprehension. Caregivers also helped direct the children.

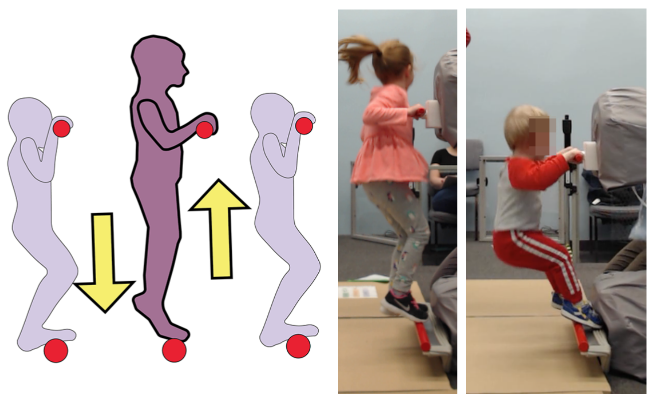


Figure 20. Illustrated instruction (left) of and children performing (center and right) the Bounce behavior.

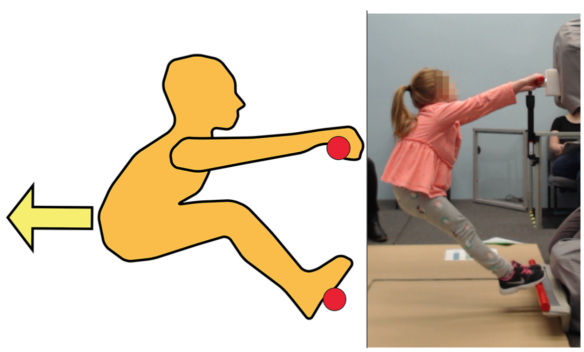


Figure 21. Illustrated instruction (left) of and child performing (right) the Lean behavior.

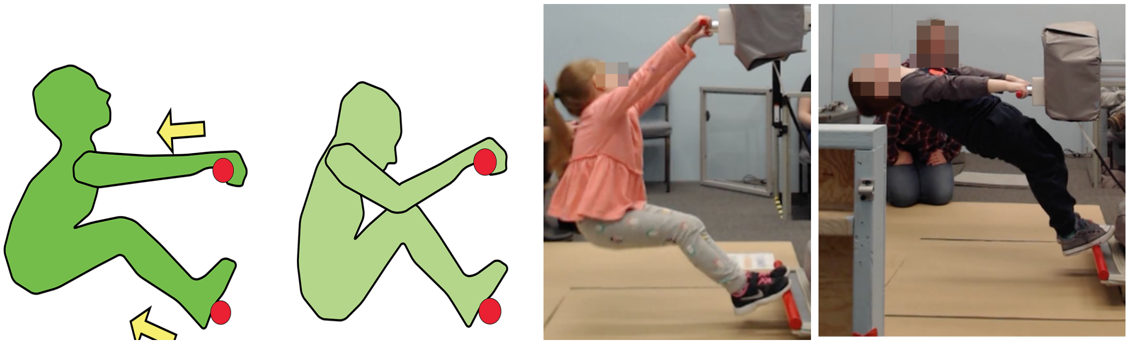


Figure 22. Illustrated instruction (left) of and children performing (center and right) the Yank behavior after leaning back.

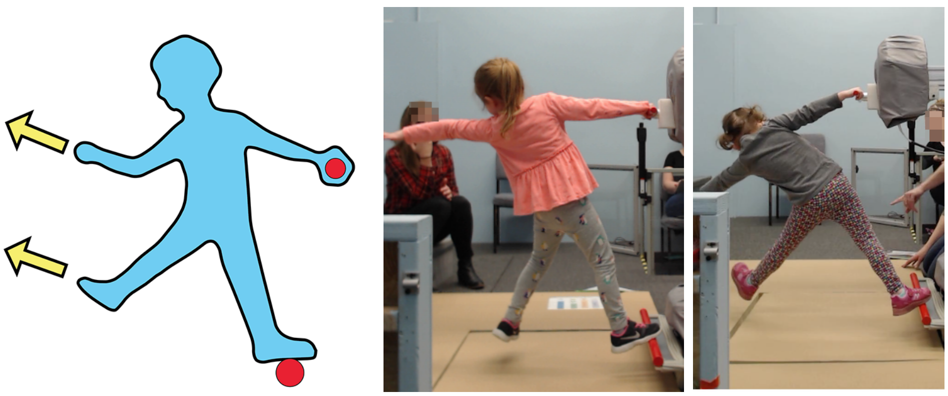


Figure 23. Illustrated instruction (left) of and children performing (right) the One-Hand/One-Foot behavior.

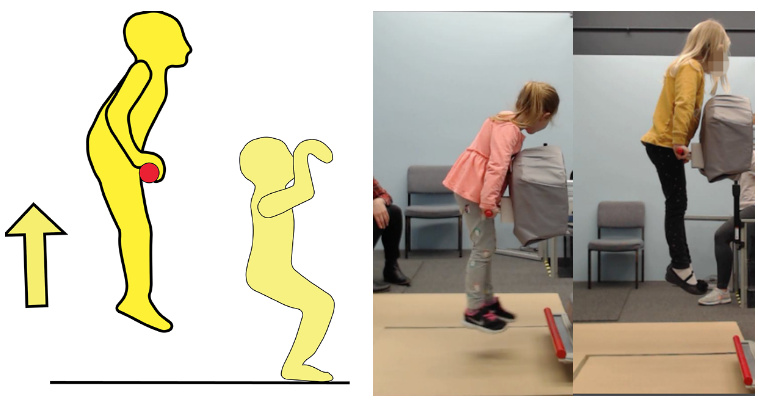


Figure 24. Illustrated instruction (left) of and children performing (center and right) the Hop Up behavior.

Figure 25. A child attempting the Hop Up behavior with the handle at high, mid and low heights (left to right).

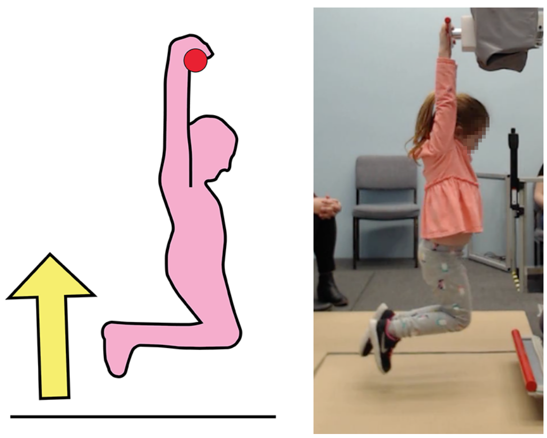


Figure 26. Illustrated instruction (left) of and child performing (right) the Hang behavior.

Data Reduction and Event Extraction

Video from each trial was reviewed to isolate the frames containing target behaviors and characterize them. The investigator recorded the start and end frame for each event. The investigator also noted if the child was applying force to something that was not instrumented during the event, such as being off the force plate or stepping on the padding over the structure, or the parent was exerting a force. These events were excluded from subsequent analysis. Tables 6–9 show the subtype categories used to identify the manner in which the child performed the tasks. Most subtypes were uncommon, qualitatively different behaviors and were not included in the analysis.

Force and moment data for each trial were reviewed for plausibility and force anomalies, with reference to still images and videos of the events. For example, in some cases the child was partially in contact with the padding behind the load cells. Some trials (<1%) were excluded due to anomalous force or moment data, generally due to behaviors that were inconsistent with the instructions. Note that the inclusion and exclusion of data was substantially subjective and biased toward inclusion of a wider range of behavior rather than a narrow interpretation of the instructions.

Table 6
Subtype Categories Used to Describe Ascent and Descent in Handle Trials

Ascent Categories		Descent Categories	
Assisted	Hop Down	1 Foot	Fall Down Posterior
Assisted Failed Attempt	Hop Up	Assisted	Foot Off
Climb Down	Knees On Bar	Assisted Failed Attempt	Hop Down
Climb Up*	Lower Bar	Climb Down*	Hop Up Landing
Climb Up 1 Hand or 1 Foot	On Bars	Climb Down 1 Hand or 1 Foot	Lower Down
Failed Attempt	Run Up Bounce Up	Climb Down Sideways	Slip Down
Fall Down Posterior	Seated	Climb Up 1 Hand or 1 Foot	Spin Down
Foot On	Swing Up	Fall	Step Down 1 Hand 1 Foot
Grey Padding	Upper Bar	Fall Down Anterior	Swing Down
		Fall Down Lateral	Swing Down 1 Hand 1Foot

* Used in analysis.

Table 7
Subtype Categories Used to Describe Bounce, Lean Back, and Yank Events in Handle Trials

Bounce Categories	Lean Back Categories	Yank Categories
Assisted	Assisted	Bent Arms or Legs*
Attempt	Bent Arms or Legs*	Failed Attempt
Bounce*	Bent at Waist*	On Ground
Climb Up	Bent Legs*	Swing Up
Failed Attempt	Failed Attempt	Yank
Hang	Lateral	Yank Assisted
Hop	Lean Back*	Yank Bent Arms or Legs*
On Floor	Null	Yank Straight Arms and Legs*
Straight Legs	On Floor	
Swing		
Tapping Feet		

* Used in analysis.

Table 8
Subtype Categories Used to Describe One-Hand/One-Foot, Hop-Up and Hang Events in Handle Trials

One-Hand /One-Foot Categories	Hop Up Categories	Hang Categories
1 Foot	Hop Up*	Face at or above bars
1 Hand 1Foot*	Hop Up On Bars*	Feet On Bars Swing
1 Hand No Feet	Hop Up On Ground*	Hang*
Anterior	On Ground	Swing*
Failed Attempt	On Ground Bar Above Waist*	
Null	On Ground Posture Not Held	
Touching Other		

* Used in analysis.

Table 9
Subtype Categories Used to Describe Ascending and Descending in the Drawer and Table Trials

Ascent Categories	Descent Categories	
Attempt	Climb Down Facing Away*	Jump Down Facing Away†
Climb In*	Climb Down Facing Box*	Jump Down Facing Box†
Failed Attempt	Climb Out*	Jump Down Facing Side†
High Step In*	Fall Out	Jump Down Facing Table†
Hop In	High Step Out*	Placed Out by Adult
No Attempt		Slide Down Facing Away*
		Slide Down Facing Table*

* Used in analysis.
† Analyzed separately.

Force and Moment Data Analysis

Handle Trials — The force data for each extracted behavior were analyzed to identify the peak forces and moments. Specifically, the peak forces in the X (fore-aft) and Z (vertical) directions were calculated along with the peak tip-over moment (hereafter moment). The moment was calculated to estimate the combined contributions of the hand and foot forces to a potential furniture tip over. Figure 27 illustrates the calculations for the handle trials. The X and Z forces from the load cells on the top and bottom handles were used. The test conditions and behaviors were essentially planar in side-view (XZ), so the Y-axis (lateral) forces were generally small and were not analyzed.

For safety reasons, most trials were conducted with the lower bar as close to the padded floor as possible and the structure was effectively rigid so that no tip over could occur. However, the effect of the child-exerted forces on the likelihood of tip over is affected by the location of the points of application of these forces relative to the effective fulcrum about which the furniture would tip (generally the front edge of the base of support). Consequently, the effects of the child-exerted forces on the likelihood of tip over were estimated by calculating moments (torques) around a virtual fulcrum, as illustrated in Figure 27.

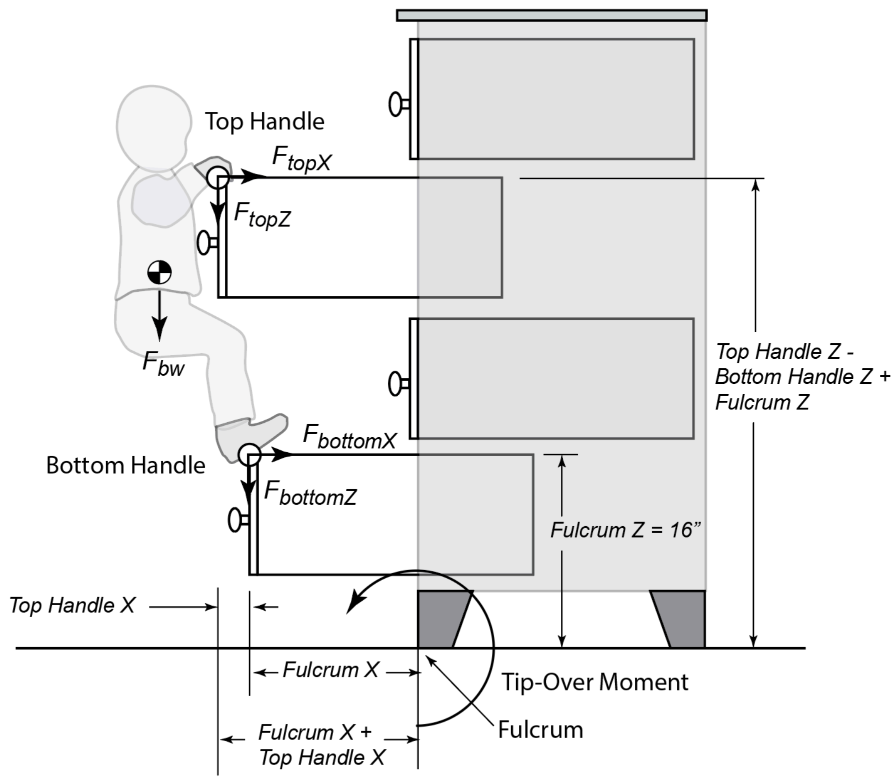


Figure 27. Schematic of moment calculations around the virtual fulcrum. Forces are positive as shown. Note that the sign of the tip-over moment is inverted for clarity, so that positive moments indicate moments that tend to tip the unit toward the child.

Based on the furniture dimension data summarized above, calculations were conducted with the fore-aft distance from the lower bar to the virtual fulcrum set to 305 mm (12 inches) and a vertical distance from the lower bar to the fulcrum of 406 mm (16 inches). These values are intended to simulate an open drawer with 90^{th}-percentile opening extent and 90^{th}-percentile height above the floor for the lowest drawer of a unit. Additional calculations were performed with various fore-aft distances (Fulcrum X values) between 0 and 16 inches to demonstrate the effects of this parameter. The tip-over moment is the instantaneous moment about the virtual fulcrum created by the X and Z forces on both bars. Note that the sign is inverted for clarity: a positive moment represents a moment that would tip a furniture unit toward the child. Considering all distances as positive and the forces positive as illustrated in Figure 27, the calculation is performed as

$$\textit{Tip-Over Moment} = F_{bottomZ} * (\textit{Fulcrum X}) - F_{bottomX} * (\textit{Fulcrum Z}) + F_{topZ} * (\textit{TopHandleX} + \textit{FulcrumX}) - F_{topX} * (\textit{TopHandleZ-BottomHandleZ} + \textit{Fulcrum Z})$$

For dimensions in feet and forces in lb, the units of the moment are lb-ft.

Figure 27 shows that the child's body weight will generally be distributed between the two bars, but that the child's center-of-mass (CM) location will also typically be outboard of the bars (farther from the fulcrum than the bars). Hence, the quasi-static moment is approximately equal to the child's CM location times the horizontal distance of the CM to the fulcrum. However, dynamic forces generated by the child during the activities in this study often produce much higher moments through the combination of horizontal and vertical forces. When a child leans back with her feet on the bottom bar and hands on the top, the horizontal forces on the bars would be equal and opposite in a quasi-static situation. In a dynamic situation, such as the Yank behavior, the horizontal forces on the top bar can be higher, resulting in a larger tip-over moment. Similarly, the Bounce behavior produces vertical forces on the bottom bar exceeding body weight, and hence higher moments than would be generated statically when Fulcrum X is greater than zero.

In some cases, the dependent measures were divided by body weight to enable the effects of the behaviors to be examined independent of child size. In these cases, the body weight normalization was applied after calculation of the moment. Calculations were performed using custom software written in the Mathematica environment (version 12.0). Unit conversions and plotting were performed in R (version 4.0.1).

Drawer and Table Trials — Tip-over moments were computed in a similar manner for the drawer and table trials. In this case, the load cells were offset from the various points of force application, so both forces and moments were included in the calculation. Figure 28 shows a schematic of the calculations. Forces and moments on the drawer front and the box of the drawer were measured separately, as described above. The moment above the virtual fulcrum was computed by adding the contributions of the forces measured at the load cell centers and the Y moments measured at each location. The virtual fulcrum location was computed relative to the front upper edge of the drawer (toward the child).

Calculating the tip-over moment from the force and moment data requires information about the locations of the load cells relative to the virtual fulcrum. Figure 28 shows the locations of the load cells relative to the front upper edge of the drawer front. Subtracting these from the virtual fulcrum X and Z dimensions (12 inches and 16 inches, respectively) gives the location of each load cell from the fulcrum. The tip-over moment attributed to each load cell is obtained by adding the measured moment about the Y axis to the moments about the fulcrum generated by the X and Z forces measured at that location.

Considering distances as positive, the moment was calculated as

$$\text{Tip-over Moment} = F_{fz}*LCFX - F_{fx}*LCFZ + M_{fy} + F_{bz}*LCBX - F_{bx}*LCFZ + M_{by}$$

where $LCFX$ = Fulcrum X – 2.75 (inches), $LCFZ$ = Fulcrum Z – 10.0, $LCBX$ = Fulcrum X – 10.3, and $LCBZ$ = Fulcrum Z – 10.3 inches.

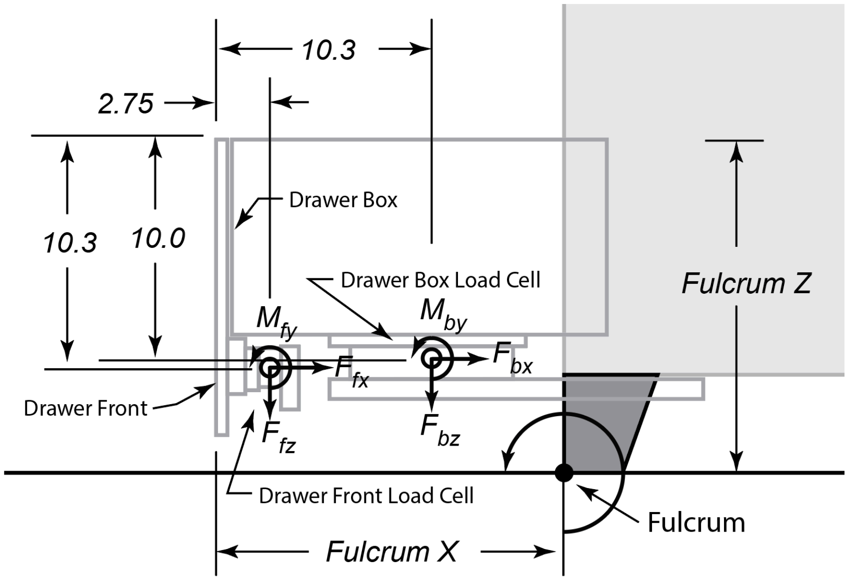


Figure 28. Schematic of dimensions (inches), forces, and moments used to compute tip-over moments for drawer and table trials.

Image-Based Posture Analysis

The video frames at time points of interest were extracted and an investigator manually digitized the series of landmarks on the image of the child. The landmarks are listed in Tables 10 and 11. Landmarks on the right side of the body were digitized for postures from the handle trials; landmarks on both sides of the body were digitized for postures from the drawer and table trials. From these landmarks, the CM location was estimated based on data from Snyder et al. (1977). In that large-scale anthropometric study, the location of the whole-body center of mass (CM) was calculated in conditions in which the child was supine with the hips and knees flexed 90 degrees. The height (inferior-superior location) of the CM with respect to the buttocks was reported as a function of erect sitting height. For children in the age range of the current study, the mean value was approximately 33%. Using this average value, the CM location was estimated as 33% of the way from the buttock landmark to the top-of-head landmark. Note that the postures of the children often deviated from the measurement posture used in the Snyder study, so this is, at best, an approximation. However, the estimated CM (ECM) location is a useful posture measure that describes the location of the lower torso (approximately the center of the abdomen).

Table 10
Landmarks Digitized on Handle Trial Video Frames

Foot Contact Right	Hand Contact Right	Top of Head
Ankle Right	Shoulder Right	Ear
Knee Right	Elbow Right	
Hip Right	Wrist Right	
Bottom of Buttocks		

Table 11
Landmarks Digitized on Drawer and Table Trial Video Frames

Ball of Foot Right	Ball of Foot Left	Top of Head
Ankle Right	Ankle Left	Nose
Knee Right	Knee Left	Ear Left
Hip Right	Hip Left	Ear Right
Hand Contact Right	Hand Contact Left	Bottom of Buttocks
Wrist Right	Wrist Left	
Elbow Right	Elbow Left	
Shoulder Right	Shoulder Left	

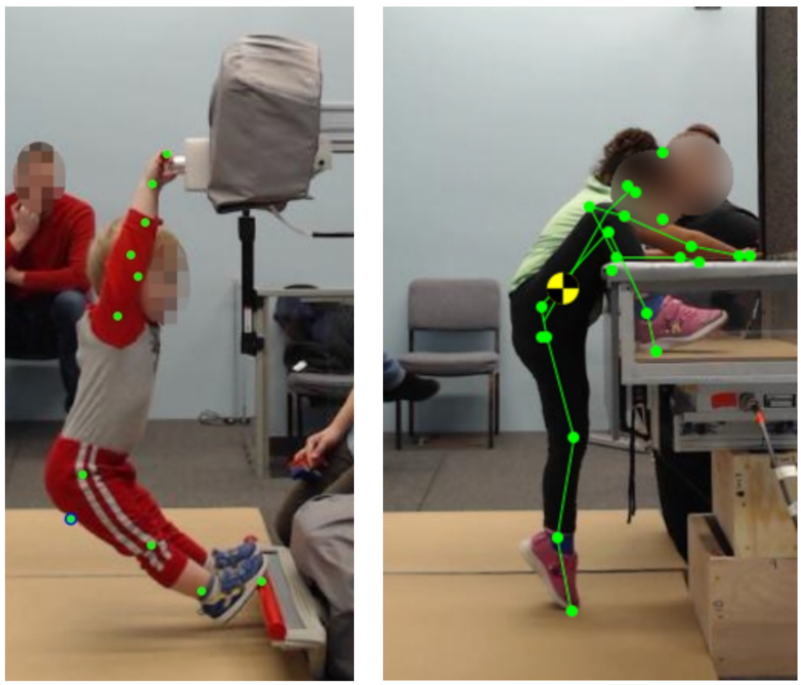


Figure 29. The photo on the left shows the right side of the body as it is digitized. The photo on the right shows the resulting body segments and the estimated center of mass locations for a different child and test condition.

RESULTS: FOCUS GROUP

Appendix G presents the full set of focus group responses. Table 12 summarizes the responses from the first two questions:

> Q1: Has your child shown an interest in climbing on a household item (not on a playground)?
>
> Q2: What was the item, where was it located and how did he/she climb?

All responded affirmatively to the first question. The reported location of climbing was most often the bedroom, followed closely by the living or family room and kitchen. The most common furniture types that children were reported to climb were tables, beds, and chairs or benches. Six of the children were reported to have climbed dressers.

When asked as part of Q2 “How does your child interact with the furniture?,” caregivers mentioned climbing tactics that included “jumped up,” “hands and feet,” “ladder style,” and “grab and pull up,” among others. Many caregivers mentioned children using chairs, stools, and other objects to facilitate their climbing, including pulling out dresser drawers.

Nearly all (95%) of children had dressers in their rooms (Q3) and 87% of caregivers had observed their children interacting with the dressers (Q4). A total of 29 children reportedly opened and closed drawers, and 16 pulled items out (only 3 put items in); 6 were reported to have climbed in or on the dresser (Q5). One caregiver reported that the child had tipped a dresser over by climbing on it. Among the climbing strategies mentioned (Q6), the most common (6 responses) was stepping into or onto the lowest drawer. Ten caregivers reported that their child climbed down from furniture, six said they jumped, and three said their child asked for help (Q7).

About half of caregivers indicated that children interact similarly with other furniture, with a range of items identified, including bookshelves, chairs, and coffee tables (Q8). Climbing and pulling up were the most common tactics.

Caregivers responded to the open question (Q9) in a variety of ways. Fifteen caregivers mentioned general tendencies to climb (monkey bars, couches, etc.); one said that they had “bolted” a TV to the wall because “6-yr-old nephew pulled dresser over on himself.” (This was a different dyad than had earlier mentioned the participant pulling over a dresser.) Given the recruitment questions, it was interesting that four caregivers mentioned that their child “doesn’t climb very much” or similar.

The subsequent questions were directed to the child (Q10-Q14). Of 32 children who responded to the initial question “do you like climbing,” 31 said yes. Asked what they climb (Q11), 23 mentioned playground equipment, 7 mentioned tables, chairs, or counters in the kitchen, 6 said bunkbeds, and 8 said couch. With respect to climbing tactics (Q12, “How do you climb?”), 15 said hands and feet, and seven had a variety of responses, including “stepping” and “by myself.” Children were asked how they interacted with a furniture item mentioned by the caregiver as something that their child had climbed (Q13). In five cases in which the caregiver mentioned a dresser, the children responded to the question “what do you do with the dresser” with opening drawers and getting clothes out. None volunteered climbing. When asked how they would get something that was hard to reach (Q14), nine mentioned chairs or stools, seven said ask for help or climb/jump, and three said “tippy toes.”

Table 12
Frequency of Caregiver or Child Mentions of Climbing by Location and Object

Item Climbed	Bed-room	Living or family room	Kit-chen or pantry	Dining room	Base-ment	Bath-room	Entry or hall	Com-puter room or office	Play-room	Any-where	Total
Table	0	2	10	5	0	0	0	0	0	0	17
Bed	16	0	0	0	0	0	0	0	0	0	16
Chair, bench and stool	0	2	5	3	0	0	1	1	1	0	13
Counter	0	0	10	0	0	0	0	0	0	0	10
Coffee table	0	8	0	0	1	0	0	0	0	0	9
Dresser	6	0	0	0	0	0	0	0	0	0	6
Shelves	0	3	2	0	1	0	0	0	0	0	6
Bunkbed	5	0	0	0	0	0	0	0	0	0	5
Crib	4	0	0	0	0	0	0	0	0	0	4
Bathtub, toilet, or towel rod	0	0	0	0	0	4	0	0	0	0	4
Desk	0	2	0	0	0	0	0	1	0	0	3
Window	0	2	0	0	0	0	0	0	0	1	3
Fireplace	0	3	0	0	0	0	0	0	0	0	3
Ottoman	0	3	0	0	0	0	0	0	0	0	3
Stairs	0	0	0	0	2	0	0	0	0	0	2
Changing table	1	0	0	0	0	0	1	0	0	0	2
Light fixture	0	0	0	1	0	0	0	0	0	0	1
Fridge	0	0	1	0	0	0	0	0	0	0	1
Baby gate	0	0	0	0	0	0	1	0	0	0	1
Other*	1	3	0	0	1	0	0	0	0	0	5
Total	33	28	28	9	5	4	3	2	1	1	114

* Toy bins or cubes, train table, pool table, play kitchen

RESULTS: HANDLE TRIALS

Qualitative Results

Figure 30 shows side-view images of examples of children's behavior on the handle fixture. The frames were taken at the time of peak tip-over moment. Forces exerted by the child at the hands and feet are illustrated using scaled vectors (red arrows). Digitized landmarks (green dots) and estimated center of mass (yellow/black circle) locations are shown. The images demonstrate that forces at both the hands and feet often have substantially horizontal components, and usually, but not always, the foot forces are larger than the hand forces. The horizontal components at the hands and feet are also in opposite directions: the horizontal foot forces are forward (toward the test fixture) while the hand forces are rearward (toward the child).

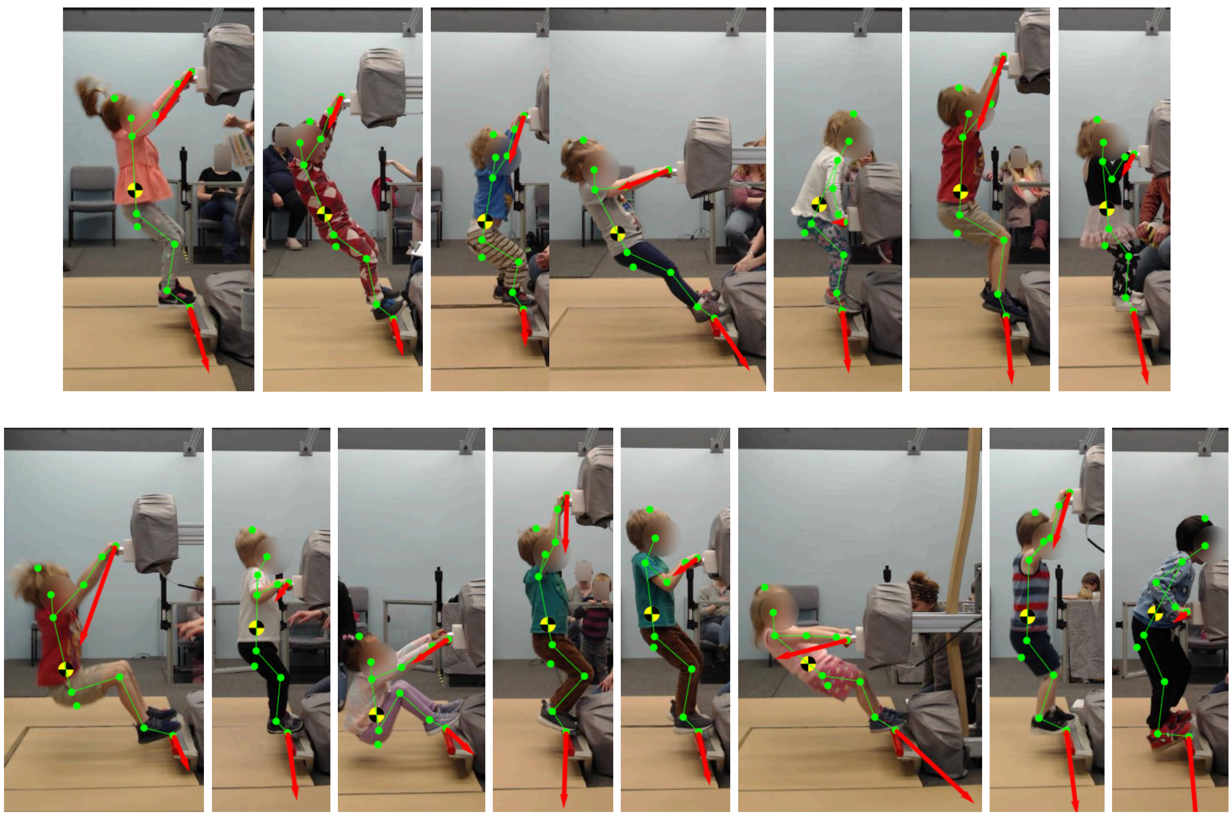


Figure 30. Examples of behaviors. Arrows illustrate the directions and relative magnitudes of forces at the hands and feet.

Overview of Forces

Figures 31– 40 show example time-history plots of the horizontal and vertical forces for each behavior. Horizontal (X) forces are positive forward, away from the child. Vertical (Z) forces are positive downward (refer to Figure 27). Figure 21 shows an Ascent behavior. In this trial, the child's body weight transitions from the force plate to the bars, with the lower bar bearing nearly all of the weight. Note that the horizontal forces on the upper and lower bars are approximately equal in magnitude and opposite in direction, consistent with the posture being approximately static toward the end of the sample. Under these conditions, the vertical forces sum to body weight.

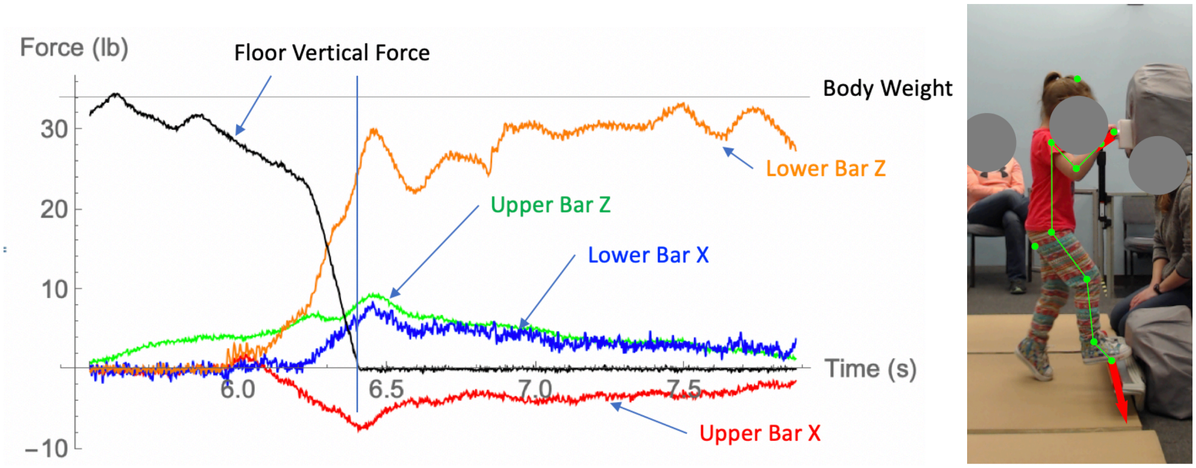


Figure 31. Example forces for the **Ascend** behavior in the handle trials. The image at the right shows the child at the time indicated by the vertical line in the figure.

Figure 32 shows data from a Bounce behavior. Here, the vertical force on the lower bar exceeds body weight even with a downward force on the upper bar, demonstrating the substantial vertical acceleration the child is producing. Again, the upper and lower bar X forces are approximately opposite. The relatively large horizontal force is necessary for the child to accelerate vertically given that the center of mass is outboard of the bars.

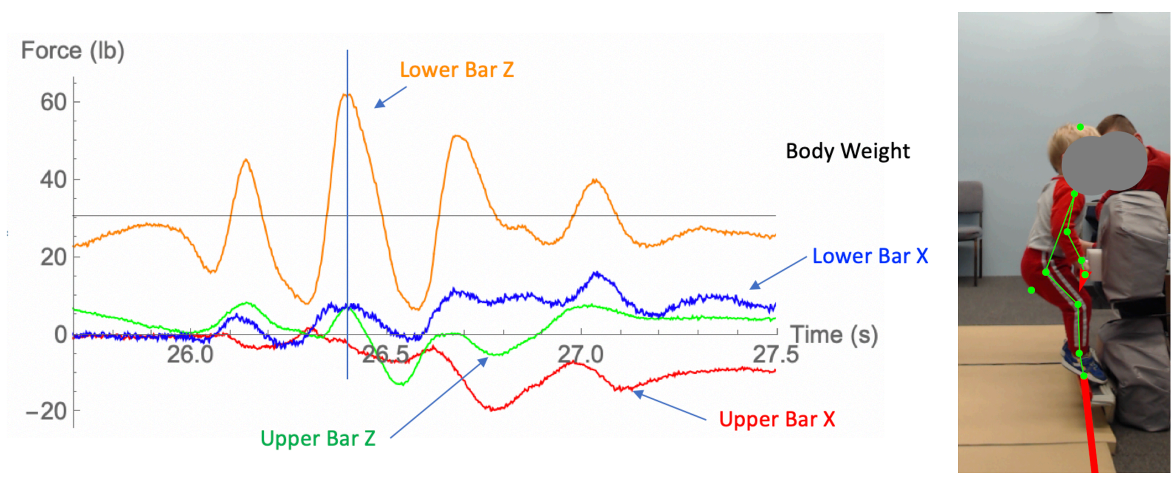


Figure 32. Example forces for the **Bounce** behavior in the handle trials. The image at the right shows the child at the time indicated by the vertical line in the figure.

Figure 33 shows data from a Lean behavior. The vertical force on the lower bar is reduced, and the upper bar vertical force increased, as the child leans back. The approximate opposite upper and lower X forces indicate that the posture is approximately static.

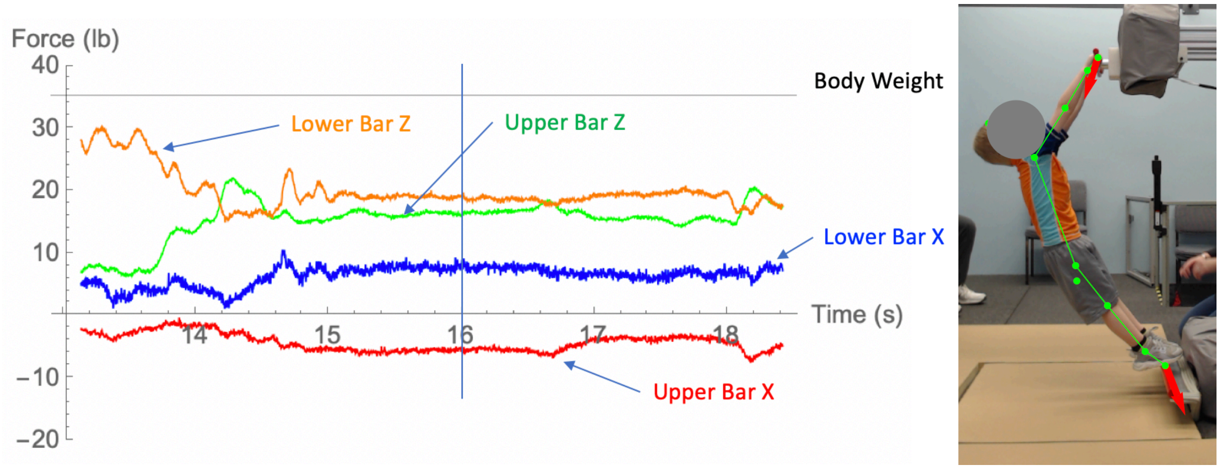


Figure 33. Example forces for the **Lean** behavior in the handle trials. The image at the right shows the child at the time indicated by the vertical line in the figure.

Figure 34 shows data from a Yank behavior. Two Yank cycles are shown, characterized by negative (rearward) peaks in the upper bar X force. Note the peak absolute magnitude of the horizontal forces on the upper and lower bars approaches or exceeds body weight. The vertical forces remain fairly constant, with most of the body weight borne by the lower bar.

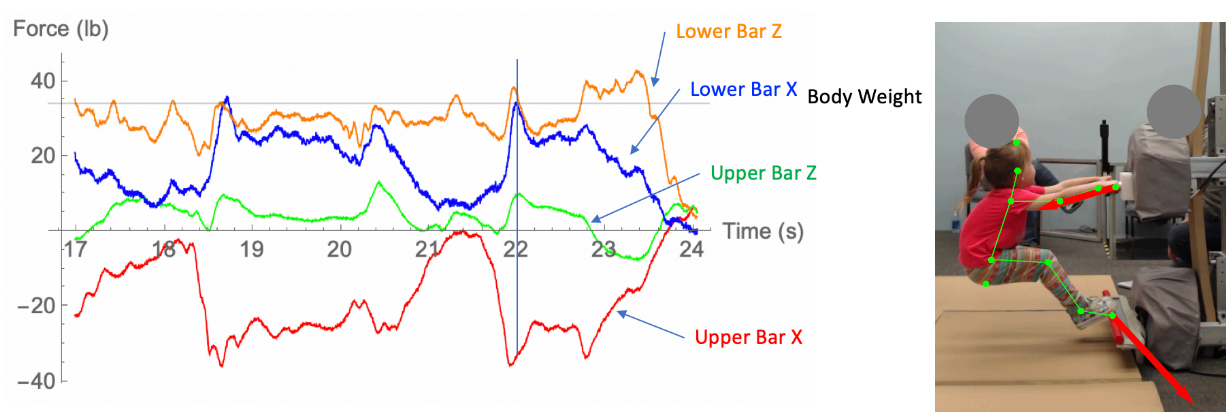


Figure 34. Example forces for the **Yank** behavior in the handle trials. The image at the right shows the child at the time indicated by the vertical line in the figure.

Figure 35 shows data from a One Hand behavior. As the child leans back, the total vertical force of approximately body weight is shared by the upper and lower bars, while the magnitudes of the horizontal forces move in parallel. The data show that this posture was approximately static for about three seconds.

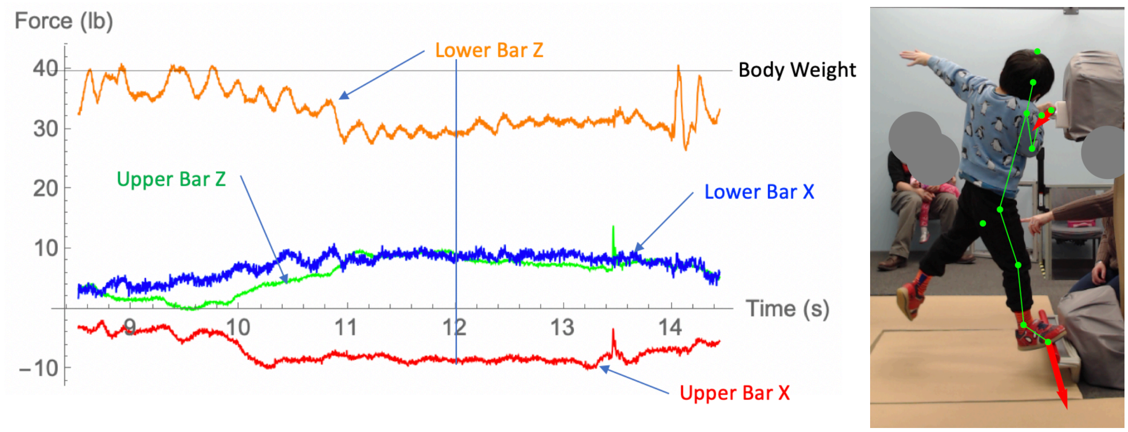


Figure 35. Example forces for the **One Hand** behavior in the handle trials. The image at the right shows the child at the time indicated by the vertical line in the figure.

Figure 36 shows data from a Hop Up behavior. No lower bar forces are observed, since this behavior was performed with the upper bar only. The upper bar vertical force approaches and briefly exceeds body weight, while the horizontal force oscillates slightly as the child tries to balance on the bar.

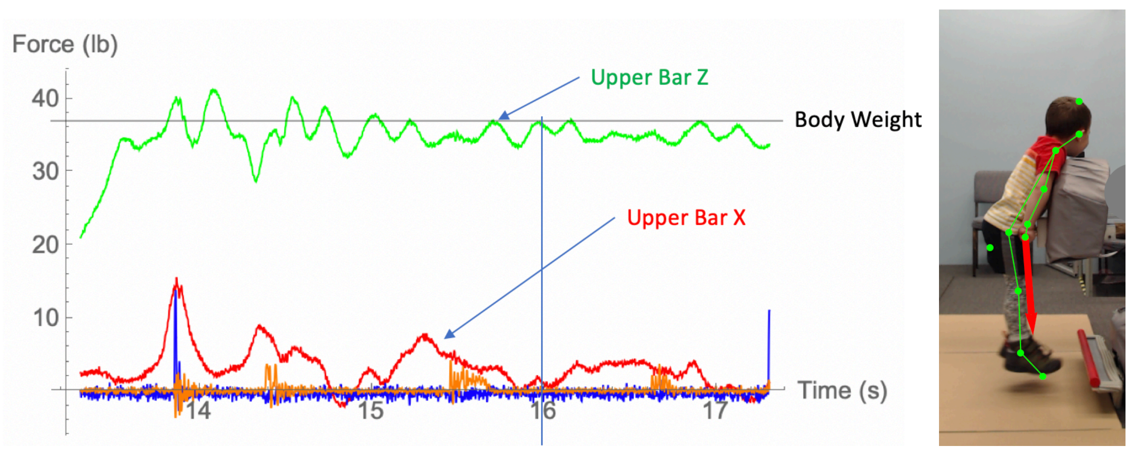


Figure 36. Example forces for the **Hop Up** behavior in the handle trials. The image at the right shows the child at the time indicated by the vertical line in the figure.

Figure 37 shows data from a Hang behavior. As with the Hop Up behavior, no lower bar forces are observed. The upper bar vertical force oscillates around body weight as the horizontal force shows some swinging back and forth. This child was able to hang for about four seconds.

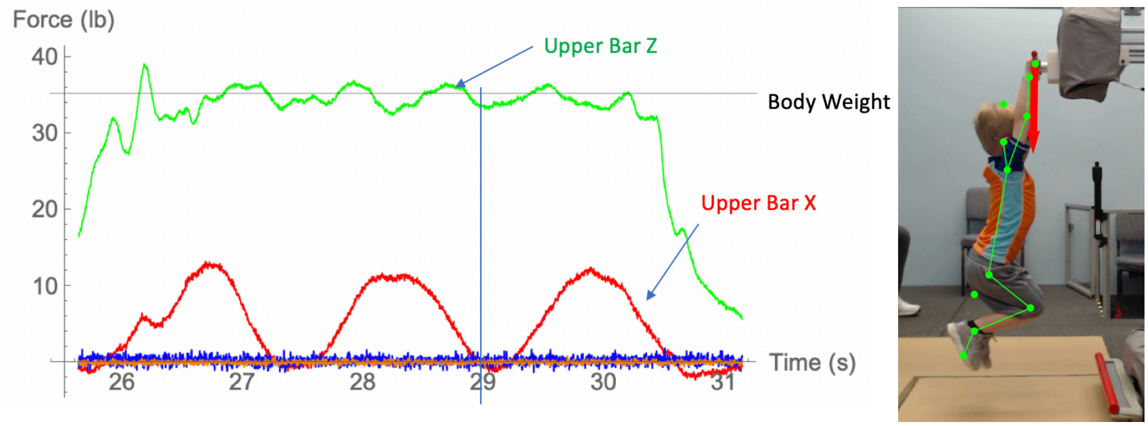


Figure 37. Example forces for the **Hang** behavior in the handle trials. The image at the right shows the child at the time indicated by the vertical line in the figure.

Figure 38 shows data from a child climbing into the drawer (ascending). The floor vertical force begins to dip below body weight as the vertical force on the front of the drawer increases. The child steps into the drawer and then, over a period of about one second, the child transfers her weight from the floor to the drawer. In this example, the child's body weight is borne by both the drawer front (note the position of the right hand) and drawer box.

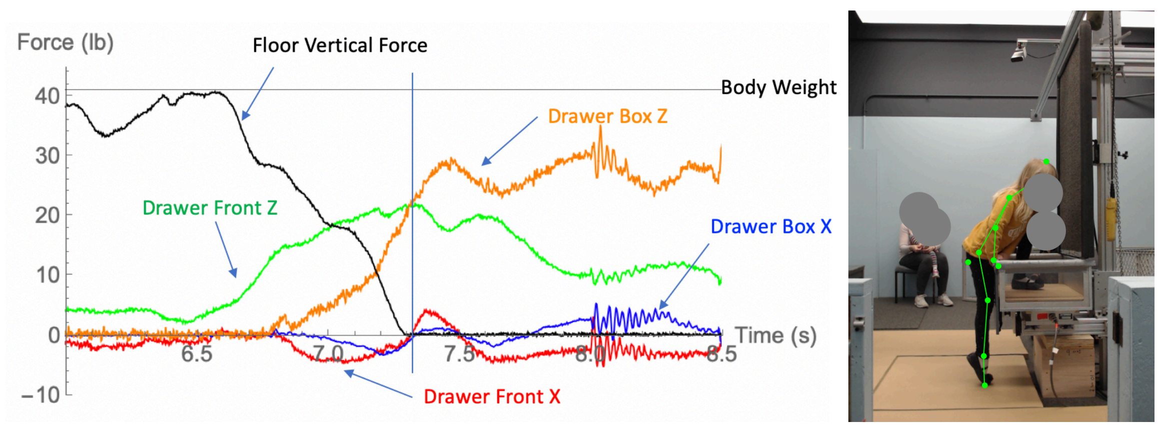


Figure 38. Example forces for the **Ascent** behavior in the drawer trials. The image at the right shows the child at the time indicated by the vertical line in the figure.

Figure 39 shows data from a child climbing out of the drawer (descending). The vertical force in the box drops initially as the child bears weight on the front of the drawer. A large amount of force, nearly up to body weight, is transferred to the front of the drawer just before the first foot touches down and the floor force increases.

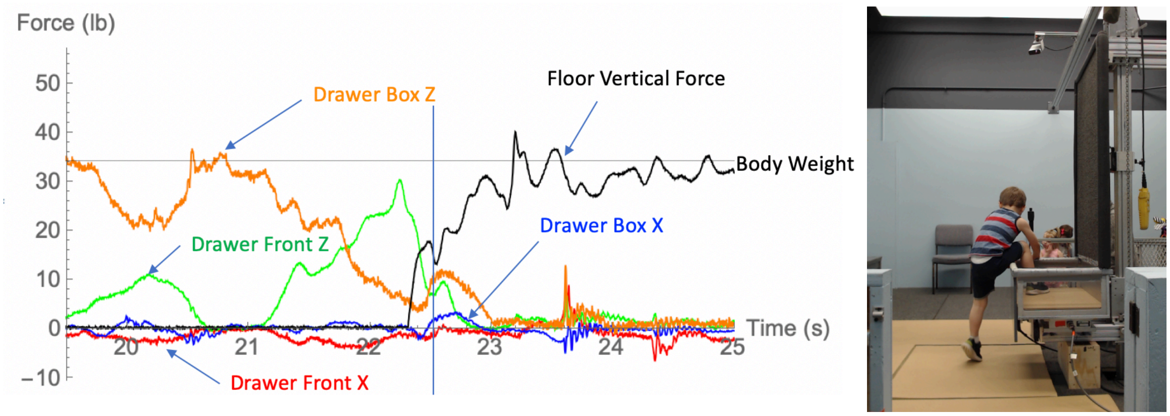


Figure 39. Example forces for the **Descend** behavior in the drawer trials. The image at the right shows the child at the time indicated by the vertical line in the figure.

Figure 40 shows data from an uncontrolled (jump) descent from the drawer. (Jump descents were not requested, but some children jumped when asked to climb down.) Note the vertical scale. The child's body weight is initially fully supported by the drawer box, then transitions to fully supported on the front of the drawer. The drawer front force drops rapidly to zero as the child begins to drop. The floor vertical force briefly exceeds more than four times body weight on landing.

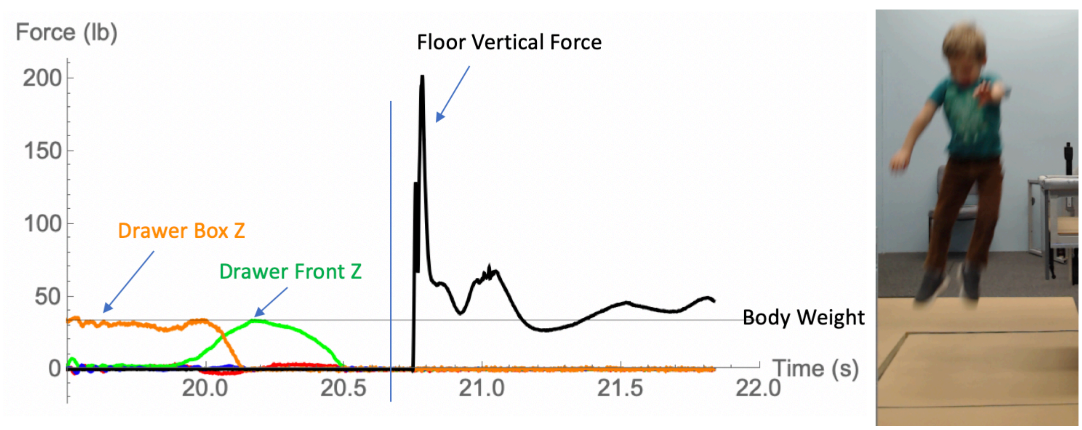


Figure 40. Example forces for a jump descent behavior in the drawer trials. The image at the right shows the child at the time indicated by the vertical line in the figure.

Maximum Moments

Figure 41 and Table 13 show box plots of the maximum moments calculated for handle trial behaviors for the 12-inch fulcrum X distance. Note that these plots consider all handle configurations, except that Ascent is only for aligned trials (upper bar over lower bar). In all cases, the median value is greater than the value that would be obtained by applying body weight at the fulcrum distance. Table 14 shows the values for aligned handle trials only (upper bar directly above lower bar). Figure 42 and Tables 15 and 16 show the values normalized by body weight. For moments in lb ft, dividing by body weight in lb yields values with units of ft. Two interpretations are useful: (1) the values are the distance from the fulcrum in feet that the body weight would need to be placed to obtain the same moment, or (2) the multiple of body weight that would need to be placed at the 1-foot distance from the fulcrum to obtain the same moment. For example, Table 13 shows that the Ascent behavior across all trials produced a mean normalized moment of 1.75, meaning that the dynamic effects produced an increase in effective body weight of 75%. Consistent with qualitative trends in Figures 41 and 42, the largest mean normalized moment was observed for the Yank behavior, with a mean value equivalent to 3.85 times body weight applied vertically to the lower bar.

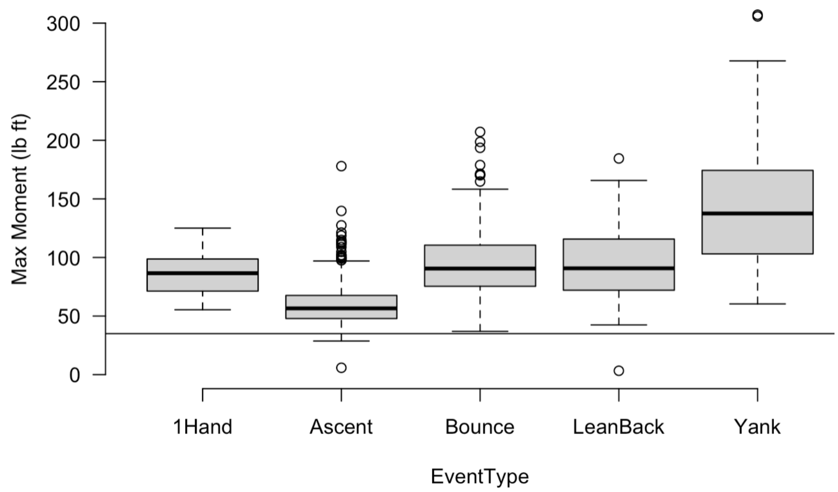


Figure 41. Box plot of maximum moment (lb ft) during behaviors calculated using a 12-inch fulcrum X distance. Horizontal line is mean body weight (34 lb) at 12 inches. In the boxplots, the dark line is the sample median, and the box shows the interquartile range (25th to 75th percentile). The whiskers (vertical lines) extend to the most extreme data point that is no more than 1.5 times the interquartile range from the box. Data points that are more extreme (generally considered outliers) are shown with circles.

Table 13
Summary of Maximum Moment Values for **All** Handle Trials (lb ft)

Behavior	N Subjects	N Trials	Mean	SD	10th%ile	50th%ile	90th%ile
1Hand	19	47	86.2	20.0	60.5	86.6	114.4
Ascend	36	436	59.6	18.5	40.3	56.6	80.8
Bounce	32	138	96.3	32.3	59.2	90.5	138.2
LeanBack	34	163	94.3	28.4	62.0	90.7	131.7
Yank	27	95	145.5	54.2	82.4	137.5	215.8

Table 14
Summary of Maximum Moment Values for **Aligned** Handle Trials (lb ft)

Behavior	N Subjects	N	Mean	SD	10th%ile	50th%ile	90th%ile
1Hand	18	32	81.3	18.5	57.0	78.9	112.4
Ascend	36	276	54.0	15.2	38.3	51.2	71.5
Bounce	32	82	91.9	29.7	58.6	87.8	133.7
LeanBack	30	83	90.7	28.5	61.2	89.3	122.9
Yank	25	53	142.4	55.1	76.2	136.6	216.2

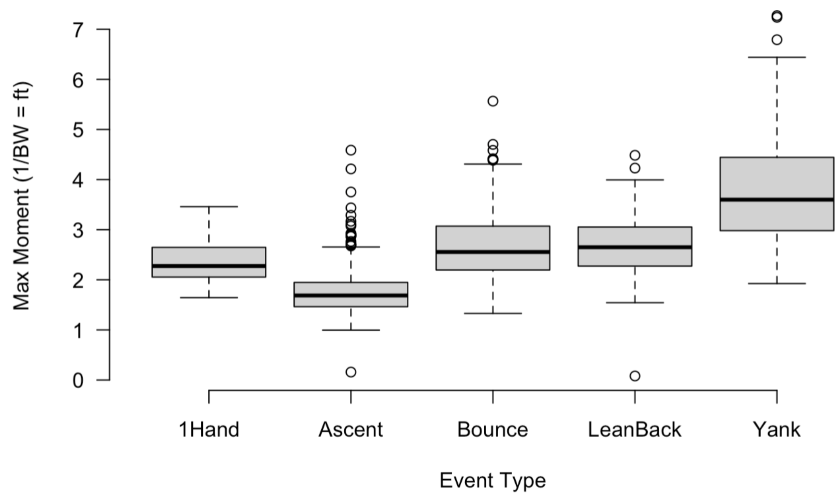


Figure 42. Box plot of maximum moment during behaviors normalized by body weight (ft).

Table 15
Maximum Moment Values (lb ft) Normalized by Body Weight (lb) for **All** Handle Trials (units: ft)

Behavior	N Subjects	N Trials	Mean	SD	10^{th} %ile	50^{th} %ile	90^{th} %ile
1Hand	19	47	2.35	0.43	1.77	2.27	2.90
Ascent	36	436	1.75	0.46	1.24	1.69	2.28
Bounce	32	138	2.69	0.72	1.90	2.55	3.57
LeanBack	34	163	2.66	0.58	2.00	2.65	3.31
Yank	27	95	3.85	1.17	2.62	3.60	5.53

Table 16
Maximum Moment Values (lb ft) Normalized by Body Weight (lb) for **Aligned** Handle Trials (units: ft)

Behavior	N Subjects	N Trials	Mean	SD	10^{th} %ile	50^{th} %ile	90^{th} %ile
1Hand	18	32	2.18	0.36	1.72	2.16	2.74
Ascent	36	276	1.60	0.39	1.21	1.54	2.00
Bounce	32	82	2.60	0.72	1.88	2.50	3.30
LeanBack	30	83	2.54	0.58	1.95	2.60	3.13
Yank	25	53	3.73	1.19	2.51	3.43	5.40

Analysis of Trends

Least-squares linear fits were conducted to examine trends in the relationship between moments and body weight. A heavier child would be expected to produce larger moments, but aspects of behavior could be more important than body weight. Note that the statistical significance of these trends is not reported due to limitations of the dataset. R^2 values are reported that quantify the fraction of variance in the moments that is accounted for by body weight. The root-mean-square deviation (RMS) from the trend line is also reported.

Table 17 lists the intercepts and slopes shown in Figures 43 and 44 showing relationships between maximum moment from child body weight for aligned trials. The R^2 values were modest, demonstrating that child behavior has more important effect on maximum moment than body weight. Even for the Yank behavior, only about 38% of the variance in maximum moment is attributable to body weight.

Table 18 and Figures 45 and 46 show trends for normalized maximum moment as a function of body weight. For Ascend and Bounce, the slopes are close to zero, but weak positive relationships are seen for Lean and Yank. This suggests a difference in behavior for larger children that is not accounted for by body weight. For example, this is consistent with the heavier children also having longer arms and legs that would allow them to shift their centers of mass further away from the handles (see section below on center-of-mass estimates) as well as being relatively stronger.

Table 17
Least-Square Fit Results relating Maximum Moment (lb ft) to Body Weight (lb) for **Aligned** Handle Trials
(see Figures 43 and 44)

Behavior	Intercept	Body Weight Slope*	R^2	RMS**
1Hand	-7.1	2.38	0.48	13.6
Ascent	8.0	1.36	0.26	13.1
Bounce	-7.7	2.82	0.30	25.0
Lean	-33.3	3.51	0.43	21.6
Yank	-79.3	5.90	0.38	43.8

* For body weight in lb
** Root mean square deviation for linear fit

Table 18
Least-Square Fit Results relating Maximum Moment Normalized by Body Weight (ft) to Body Weight (lb) for **Aligned** Handle Trials
(see Figures 45 and 46)

Behavior	Intercept	Body Weight Slope *	R^2	RMS**
1Hand	1.94	0.006	0.00	0.36
Ascent	1.80	-0.006	0.00	0.39
Bounce	2.37	0.006	0.00	0.72
Lean	1.47	0.030	0.07	0.56
Yank	1.19	0.068	0.09	1.12

* For body weight in lb
** Root mean square deviation for linear fit

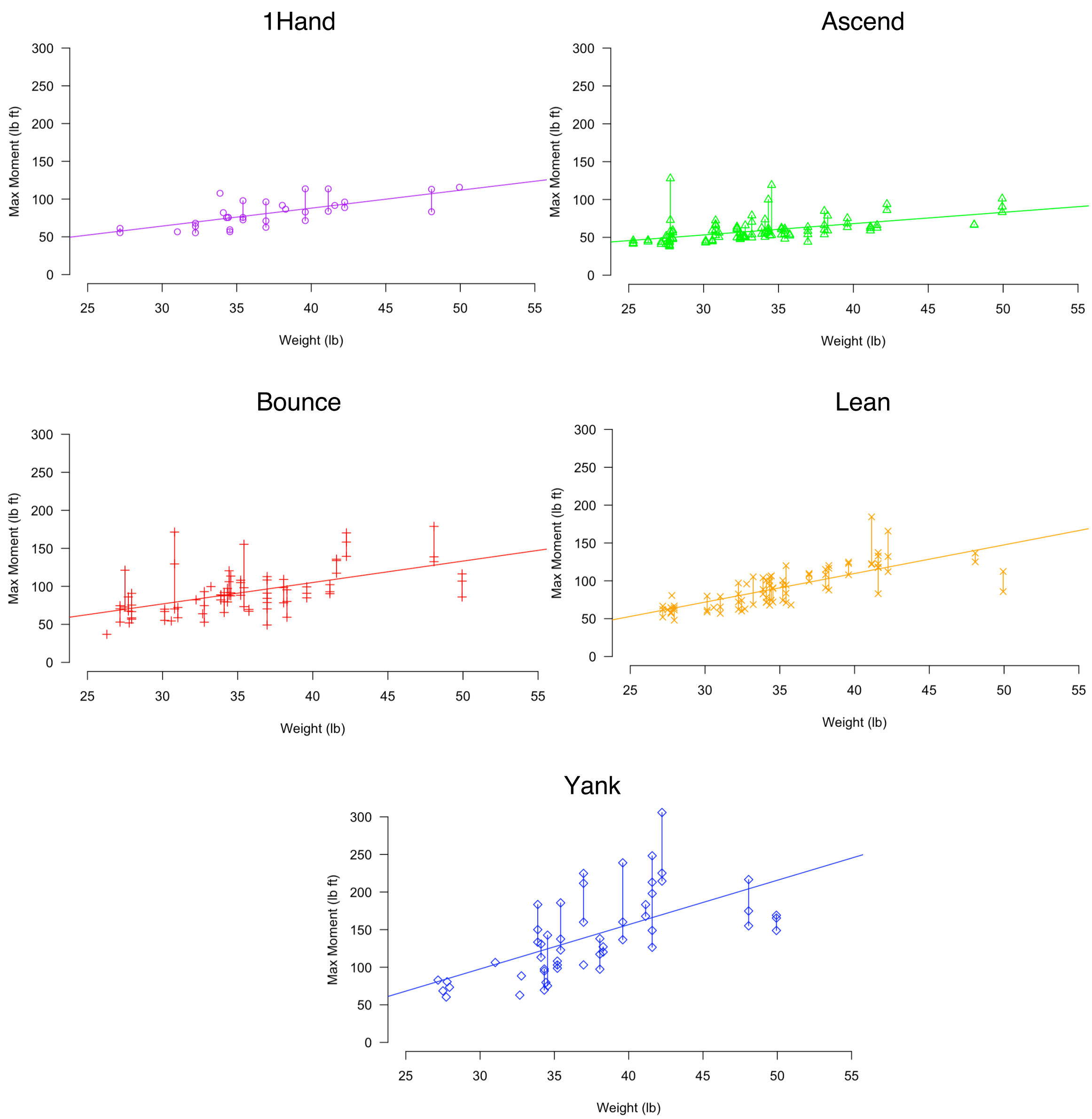


Figure 43. Maximum moment (lb ft) as a function of body weight (lb) for **aligned** handle trials. Vertical lines connect data from the same subject. Trend lines are shown for each behavior.

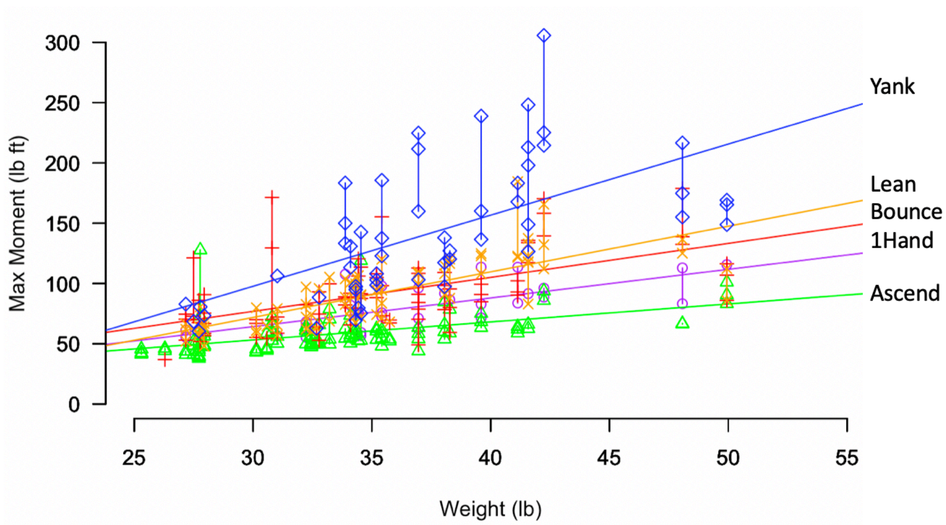


Figure 44. Plots from Figure 43 combined.

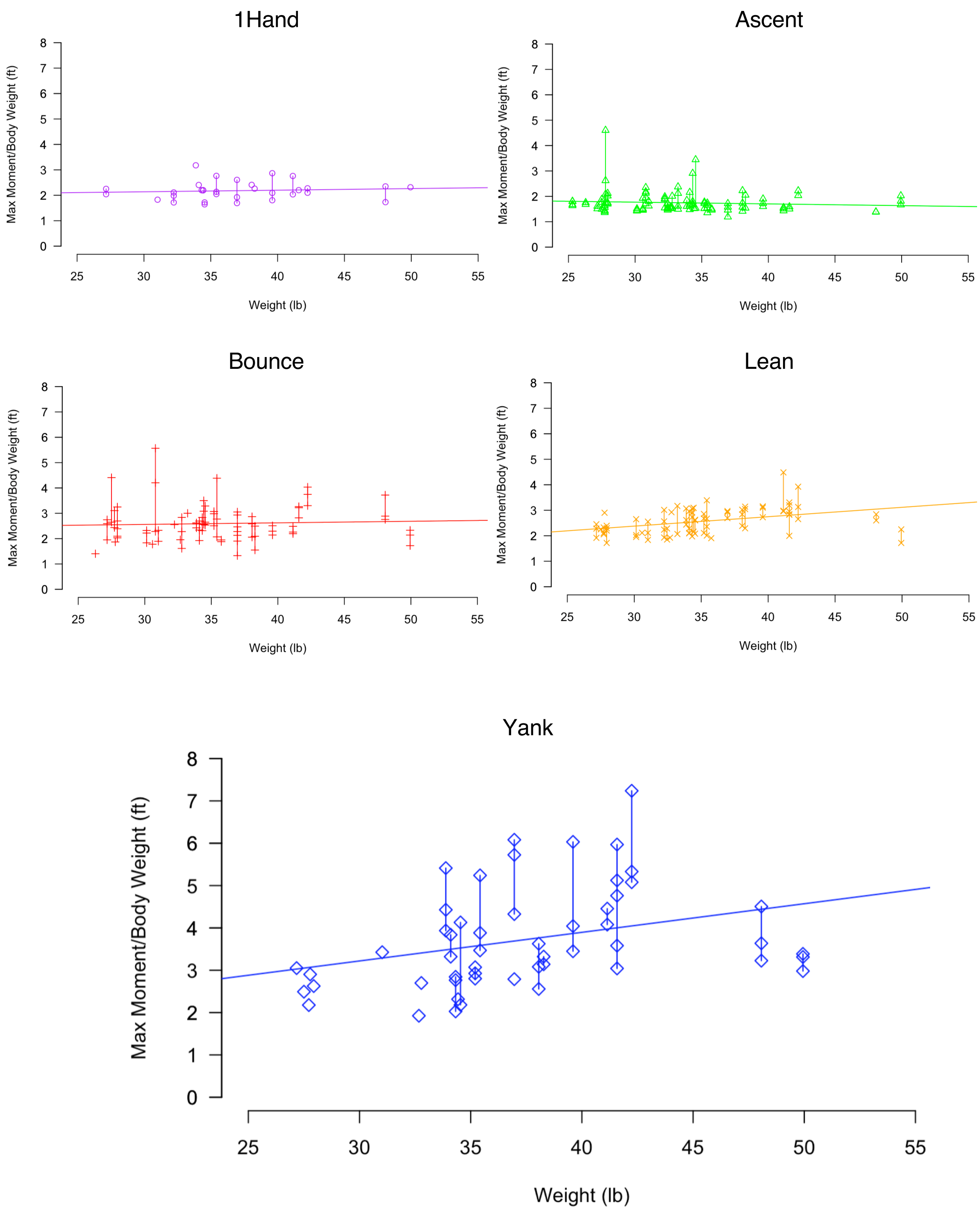


Figure 45. Scatter plots of maximum moment (lb ft) normalized by body weight (normalized units: ft) as a function of body weight (lb) for **aligned** handle trials. Vertical lines connect data from the same subject. Trend lines are shown for each behavior.

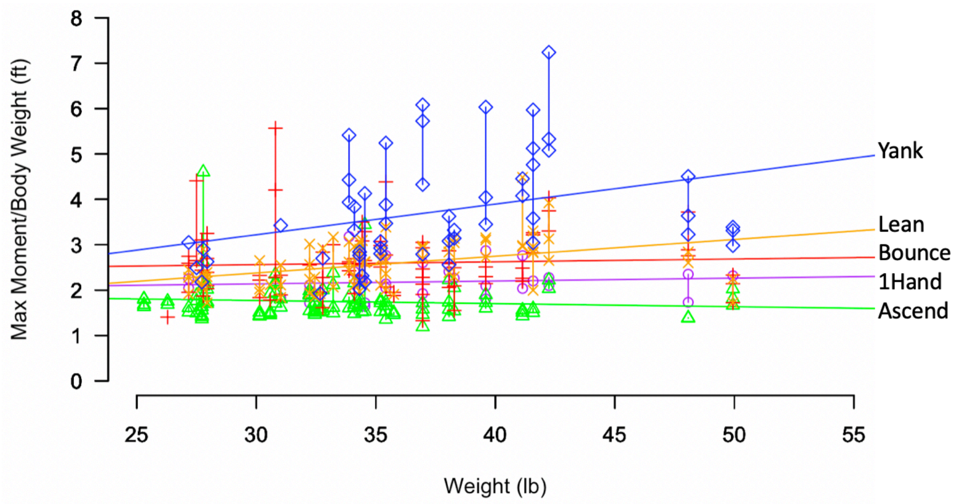


Figure 46. Plots from Figure R6 combined. Vertical lines connect data from the same subject. Trend lines are shown for each behavior.

Hop Up and Hang

The Hop Up and Hang behaviors were designed to use the upper handle only and were performed only in the trials in which the upper handle was offset toward the child. Because the fore-aft location of the upper handle was scaled based on body size (see Methods), the tip-over moment was calculated differently for these behaviors. The vertical force on the upper bar was assumed to be the only relevant force and the virtual fulcrum was set at 12 inches forward of the upper bar. Effectively, this means the vertical force in lb is equal to the value of the tip-over moment in lb ft.

Figure 47 shows these normalized moment values, which show minimal trends with body weight. The mean values (standard deviations) for Hop Up and Hang were 0.91 (0.35) and 1.14 (0.12) ft. The 62 available hop-up trials included a variety of tactics and both successful and unsuccessful tries (that is, where the child was not able to hold the posture). The 22 hang trials are only successful efforts (held for at least one second).

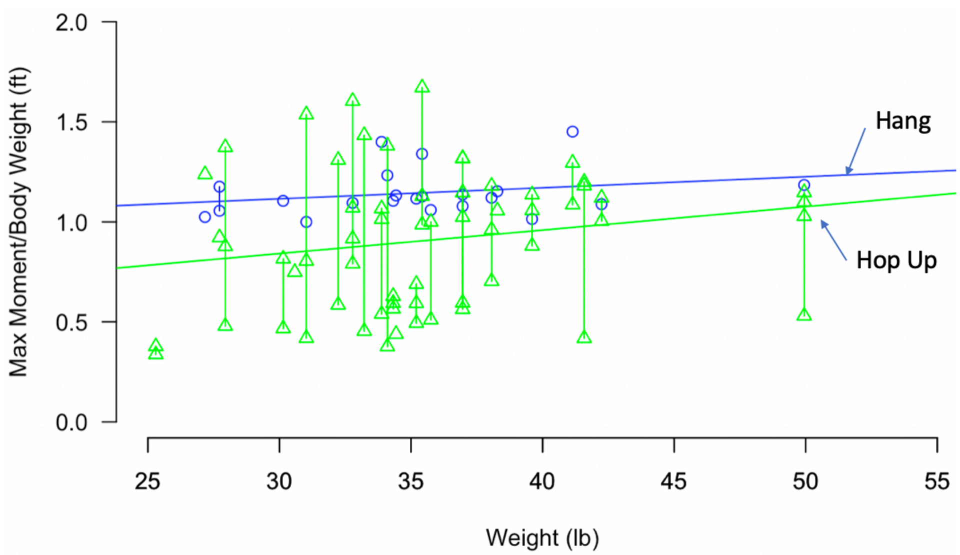


Figure 47. Maximum moment (lb ft) normalized by body weight (normalized units: ft) as a function of body weight for Hop Up and Hang behaviors. Vertical lines connect data from the same subject. Trend lines are shown for each behavior.

Vertical Forces

Examining the vertical forces on the handles at the time of maximum tip-over moment provides insight into the factors that produce the moments. Figure 48 shows the sum of the vertical forces on the upper and lower handles at the time of peak moment normalized by body weight. Conceptually, a stationary child will produce vertical forces equal to body weight, and indeed the figure shows that median forces for the quasi-static behaviors (1Hand, Hang, and Lean) are very close to one body weight. The highest normalized vertical forces are observed for the bounce behavior, with a mean of 1.7 times body weight. However, the values are lower for the lean and yank behaviors that produced higher tip-over moments. These findings show the importance of center of mass location for generating tip-over moment. Whereas the high tip-over moment for the Bounce behavior is generated predominantly by dynamic vertical acceleration of the child's mass, the high moments for Lean and Yank are due primarily to the outward offset of the child's CM from the handles, rather than vertical forces higher than body weight. (Note that the Yank behavior also results in differential horizontal forces that contribute to the tip-over moment, but the dominant factor is the CM location.) This analysis also makes clear that the child's weight, by itself, does not completely determine tip-over moment, nor does the vertical force. Both the CM location and dynamic behaviors are also important.

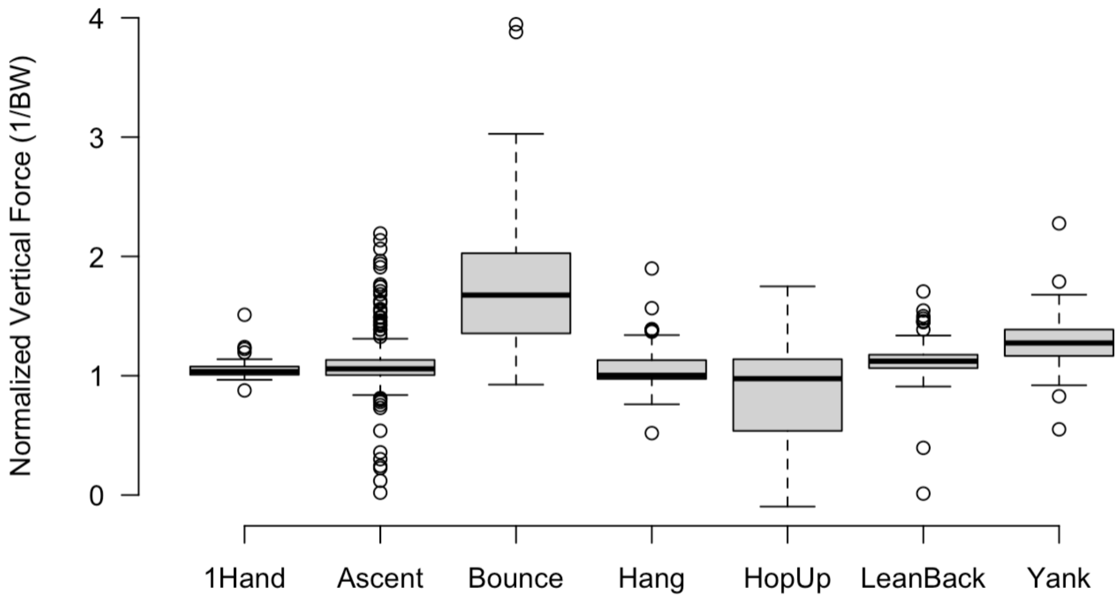


Figure 48. Normalized vertical forces (sum of upper and lower handles) at time of peak moment.

Effects of Vertical Handle Placement

The spacing between the upper and lower handles was varied based on participant anthropometry to ensure that all participants produced a wide range of postures independent of body size (see Figure 19). The effects of the nominal upper handle height (high, medium, low) on the mean tip-over moment was examined within behavior. Figure 49 shows boxplots of the differences in moment distribution across upper bar height in the aligned conditions. Table 19 lists the mean values and standard deviations within conditions. Apparent differences are observed only for the Ascent and Lean behaviors. For Ascent, the mean moment was higher in the mid and high bar positions than in the lower bar position. For Lean, the mean moment was higher in the lower bar position, which allowed the participants to extend their bodies fully rearward than in the higher handle positions. A comparison of the moments for all ascent conditions with those for the high step (lower bar) height did not show meaningful differences. In all cases, the variability within conditions was large relative to the differences between conditions.

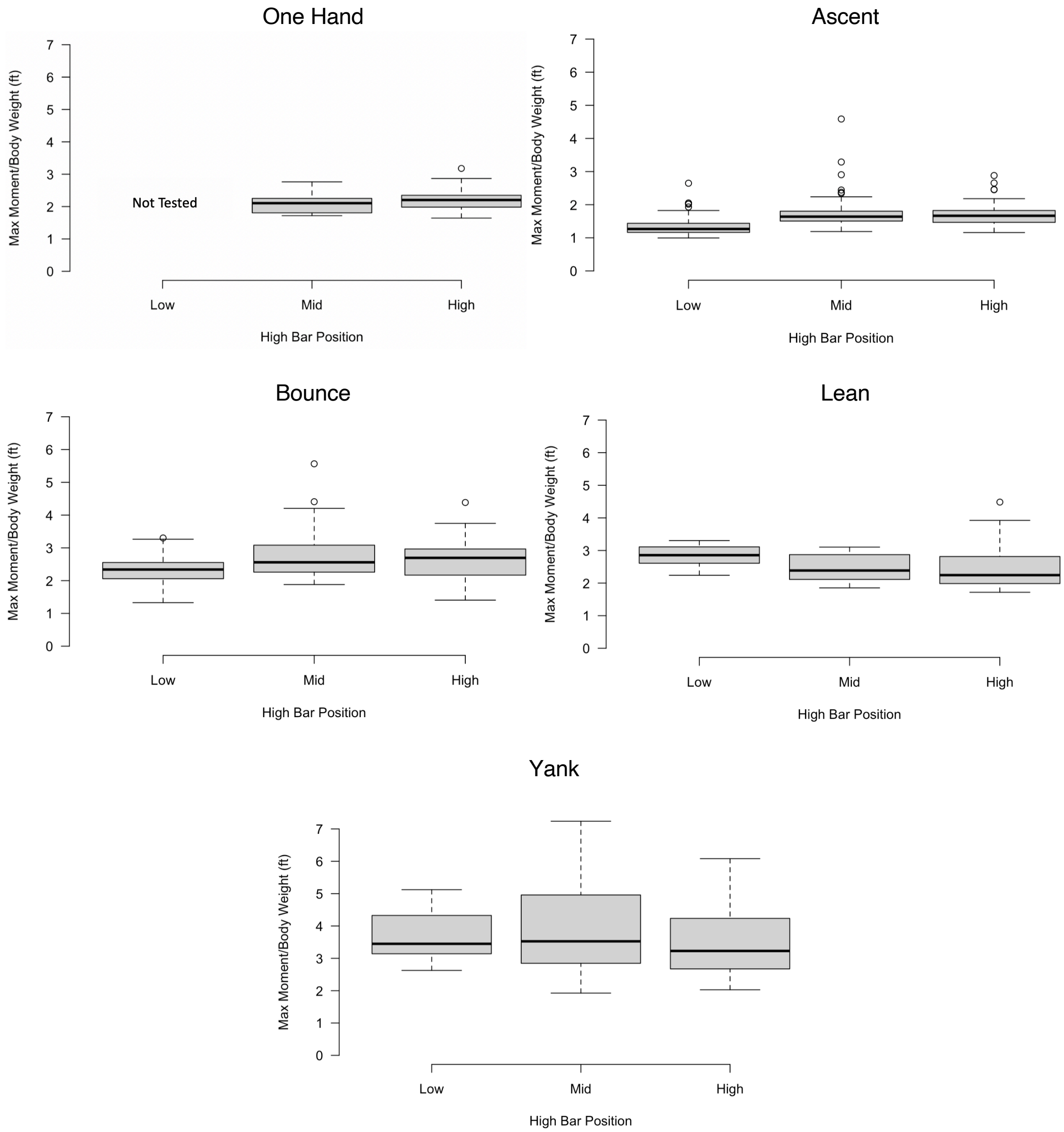


Figure 49. Effects of upper bar height on normalized moment in aligned trials.

Table 19
Effects of Upper Handle Placement on Mean Normalized Moment in Aligned Trials (ft)

Behavior	Low		Mid		High	
	Mean	SD	Mean	SD	Mean	SD
1Hand	N/A	N/A	2.12	0.32	2.23	0.41
Ascent	1.36	0.29	1.73	0.41	1.67	0.31
Ascent High*	1.39	0.25	1.70	0.34	1.67	0.21
Bounce	2.30	0.49	2.78	0.85	2.67	0.66
Lean	2.83	0.32	2.47	0.40	2.48	0.71
Yank	3.68	0.79	3.93	1.46	3.55	1.21

* Bottom bar in high position.

Effects of Virtual Fulcrum Placement

The distance that forces are exerted from the fulcrum affect the moment. In particular, the horizontal (X) fulcrum position has a strong effect, since downward forces are generally highest in these activities. The preceding analysis was based on a 12-inch (one foot) horizontal distance between the location of force exertion and the fulcrum, chosen because it is the 90th percentile value for drawer extension in a large dataset of clothing storage unit dimensions. Because this dimension varies across furniture designs, the effect of this dimension on the moment is important to examine.

In the static case, where the sum of the vertical forces is equal to body weight, the moment is equal to body weight times the horizontal distance from the child's center of mass to the fulcrum. Because the center of mass is always outboard of the hands and feet in these scenarios, reducing the fulcrum X to zero reduces, but does not eliminate, the moment. Under static conditions, the fore-aft forces at the hands and feet will be equal and opposite; the moment caused by the CM lying outward of the hands and feet is observed in the data as the magnitude of the force at the hands multiplied by the distance between the hands and feet.

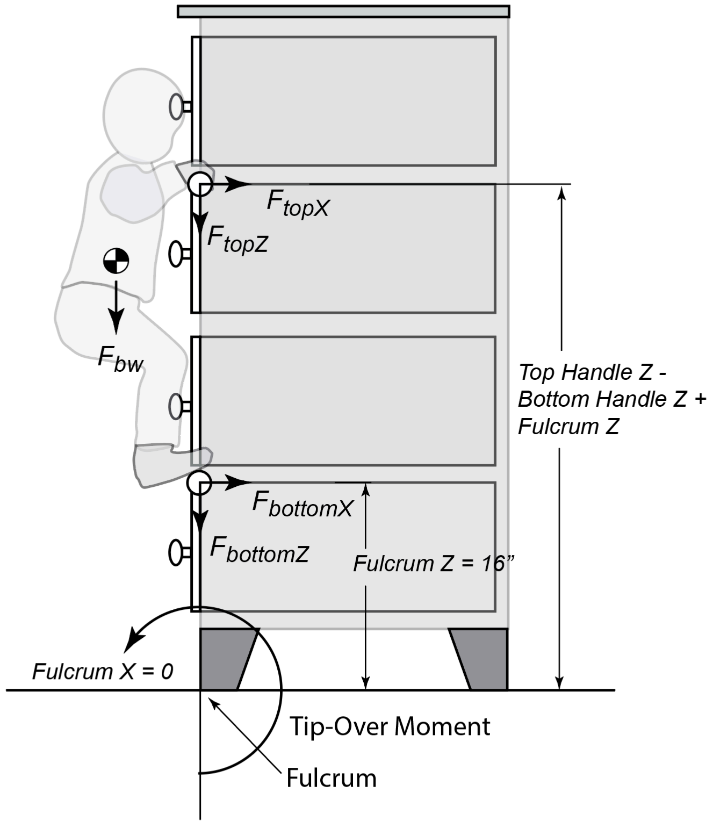


Figure 50. Schematic of effects of reducing fulcrum X to zero (compare with Figure 27).

Because the behaviors of interest are dynamic, the quasistatic calculations do not necessarily hold. However, the net moment can be calculated using a zero fulcrum X position to bound the effects of drawer extension. Placing the virtual fulcrum directly under the hands and feet in the aligned conditions eliminates the effects of vertical forces on moment while amplifying the relative effects of horizontal forces.

Table 20 compares the mean peak moments for fulcrum X values of 0 and 12 inches across behaviors for aligned conditions. The time of peak moment can differ depending on the fulcrum position used. However, to facilitate comparison, the moments for X=0 inches were calculated using the forces measured at the time of peak moment calculated using X=12 inches. Figure 51 shows the effects across the range of fulcrum X values. The trends are linear because the calculation is in effect scaling the moment created by the vertical forces to zero. Hence, the moment that remains with X=0 is due entirely to horizontal forces.

Placing the fulcrum directly under the aligned handles (X=0) reduces but does not eliminate the moment. The normalized values can be interpreted as the effective CM location outboard of the front of the clothing storage unit, in feet. The mean value is about 0.5 feet for the Ascent behavior and about 2.5 feet for the Yank behavior, where the horizontal forces exerted at the hands create substantial moments even when the effects of vertical forces are eliminated.

Table 20 also shows the effects of reducing Fulcrum Z to zero. The effect is much smaller than the effect of Fulcrum X, since the vertical forces (due to body weight) are generally much larger than the horizontal forces. The largest effect is seen for the Yank behavior, which has the highest horizontal forces. Figure 52 shows the trends across Fulcrum Z values.

Table 20
Effects of Virtual Fulcrum X Position on Mean Values of Maximum Moment (Aligned Trials)†

Behavior	X = 12" Z = 16" (Reference)	X = 0" Z = 16"	X Difference Relative to Reference*	X % Difference*	X = 12" Z = 0"	Z Difference Relative to Reference*	Z % Difference*
1Hand	81.3	42.0	-39.3	-48.3%	74.4	-6.9	-8.5%
Ascend	54.1	17.5	-36.6	-67.7%	49.9	-4.2	-7.8%
Bounce	91.9	26.8	-65.1	-70.8%	87.7	-4.2	-4.6%
LeanBack	91.7	51.9	-39.8	-43.4%	82.2	-9.5	-10.4%
Yank	142.4	94.1	-48.3	-33.9%	118.2	-24.2	-17.0%

† Moments for X=0 calculated using the force values measured at the time of peak moment calculated with X=12 inches. Fulcrum Z = 16 inches for both Fulcrum X columns; Fulcrum X = 12 inches for Fulcrum Z column.
* Difference in moment going from 12 inches or 16 inches to 0 inches.

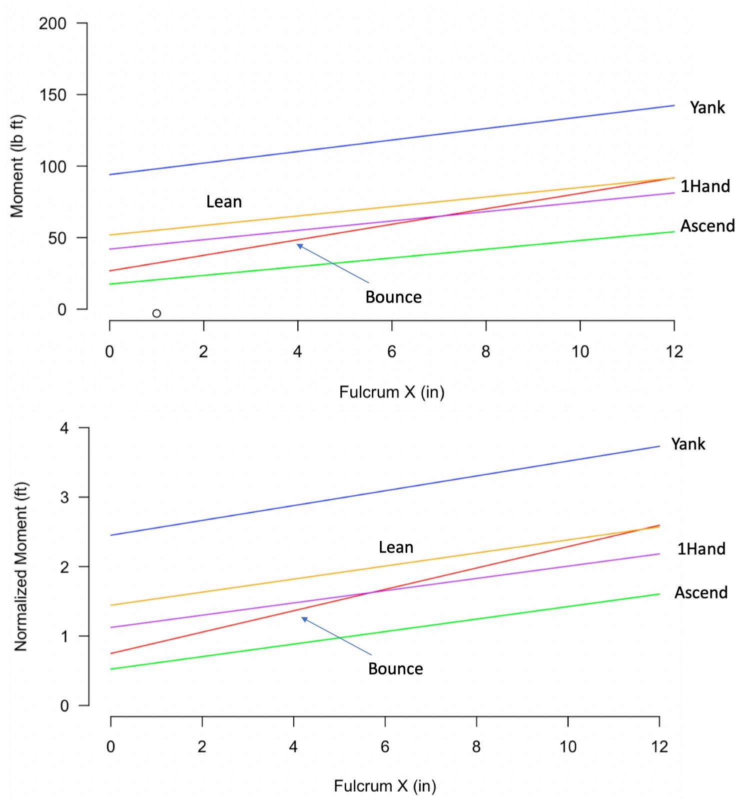
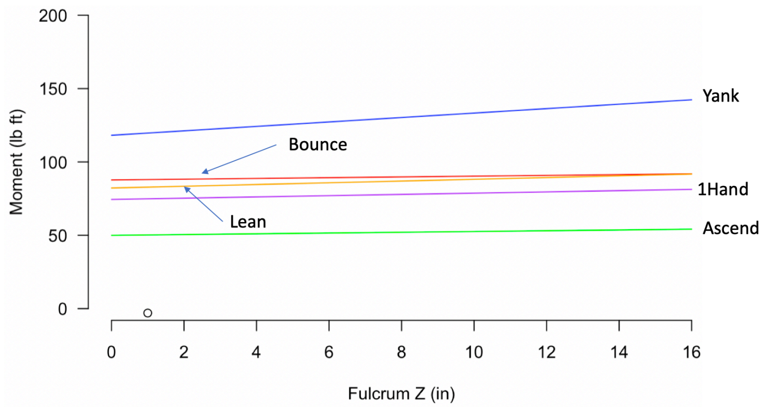


Figure 51. Effects of varying the horizontal distance to the virtual fulcrum from zero (directly under the bars) to 12 inches on moment (top) and moment normalized by body weight (bottom) for aligned trials.



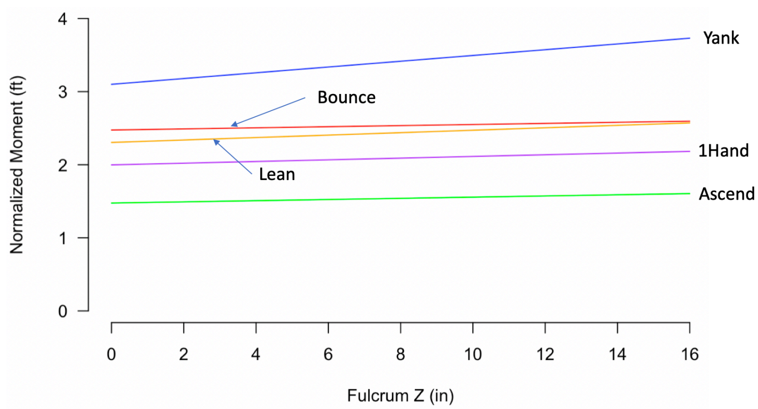


Figure 52. Effects of varying the vertical distance to the virtual fulcrum from zero (bottom bar at ground level) to 16 inches on moment (top) and moment normalized by body weight (bottom) for aligned trials.

Posture Results: Center of Mass Location

Participant postures have strong effects on the forces exerted and the calculated moments, because most of the force magnitude results from the action of gravity on the participant's mass. Consequently, the location of the center of mass (CM) during the behavior is the most useful posture variable. If the postures were static, the CM location could be calculated from the measured forces. However, due to the dynamic nature of the behaviors, the CM location is best estimated from video images. Note that due to resource limitations CM location was estimated for only a subset of trials.

The calibrated point locations digitized images were analyzed to quantify the estimated CM (ECM) location relative to the fore-aft position of the handles for a subset of the aligned-condition trials (see Methods section for digitizing and CM estimation procedures). For each trial, the frame from the sideview video at the time closest to the time of maximum moment was digitized (Figure 53)

Table 21 lists summary statistics for the ECM offset. Figures 54 and 55 show the ECM offset as a function of child body size for four behaviors. The results show that the results can be summarized as two postures: one for Ascent and Bounce behaviors with the ECM about 6 inches from the handles, and another for the Lean and Yank behaviors with the mean ECM of about 11 inches. Note that the variance is much larger for the latter two behaviors, consistent with the greater postural flexibility afforded by these behaviors. Figures 54 and 55 show that the ECM is related to body size, as expected, with larger children having their CM further away from the handles. The effect is stronger for the Lean and Yank behaviors. However, the variance around the mean trend is fairly large, indicating substantial posture variability. Note that the correlation between stature and body weight in this sample is 0.84, so the similar relationships with ECM are expected.

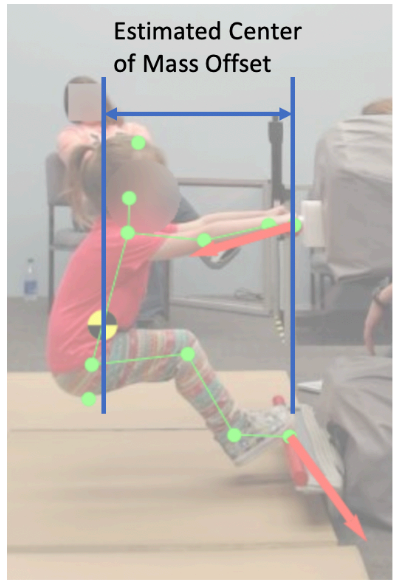


Figure 53. Example of digitized frame with estimated center of mass location and offset from upper handle. Forces at the hands and feet are shown with scaled arrows.

Table 21
Estimated Center of Mass Horizontal Offset from the Handles for Aligned Trials (inches)

Behavior	N Subjects	N Trials	Mean	SD	10th %ile	50th %ile	90th %ile
Ascent	36	109	6.1	2.0	4.3	6.1	8.6
Bounce	32	80	6.0	2.5	4.0	5.8	9.1
LeanBack	30	81	11.3	3.4	8.5	11.6	15.9
Yank	25	53	10.9	3.4	7.3	11.5	15.9

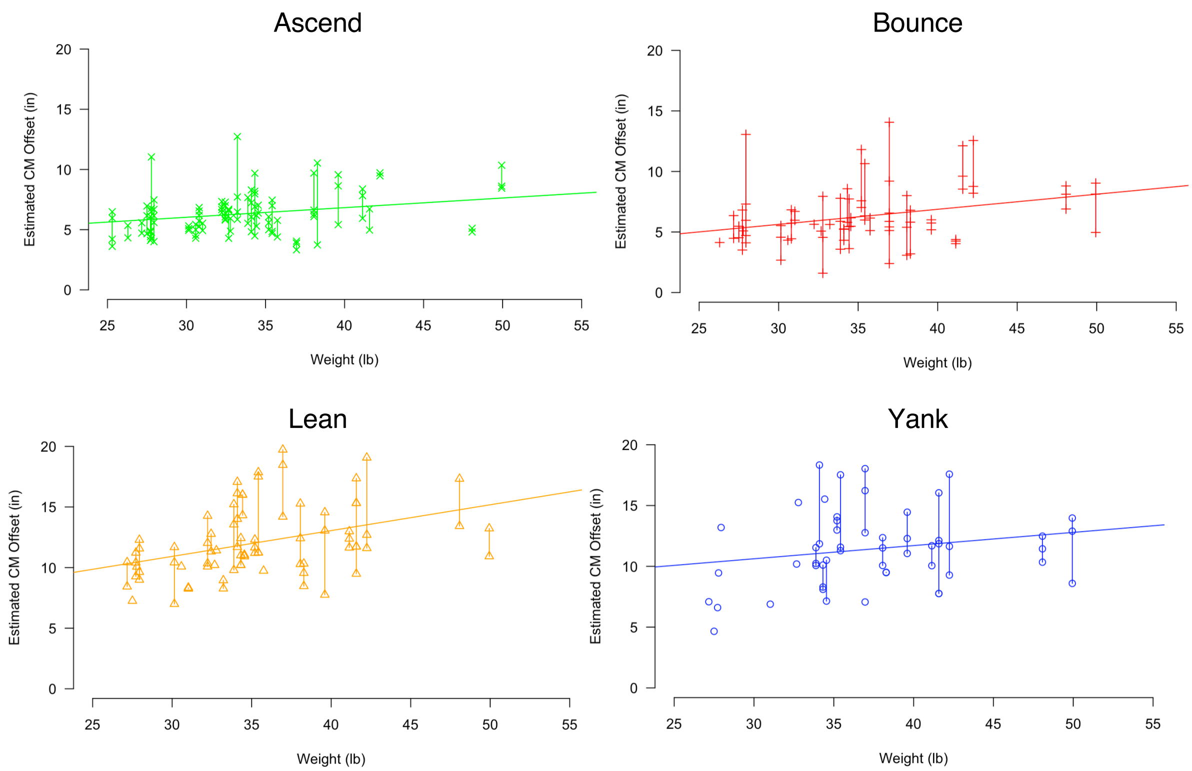


Figure 54. Relationship between estimated CM offset and **body weight** for aligned trials for which posture was analyzed.

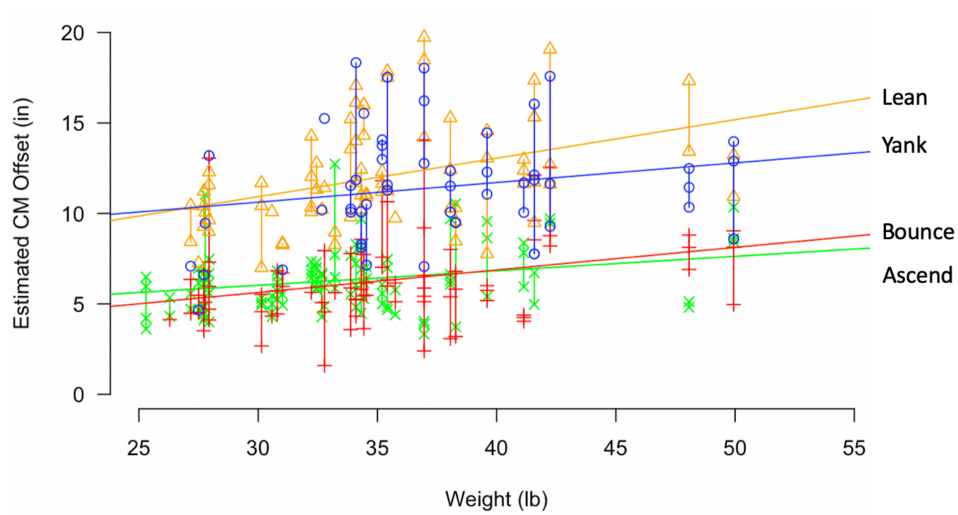


Figure 55. Relationship between estimated CM offset and **body weight** for aligned trials for which posture was analyzed (summary across behaviors).

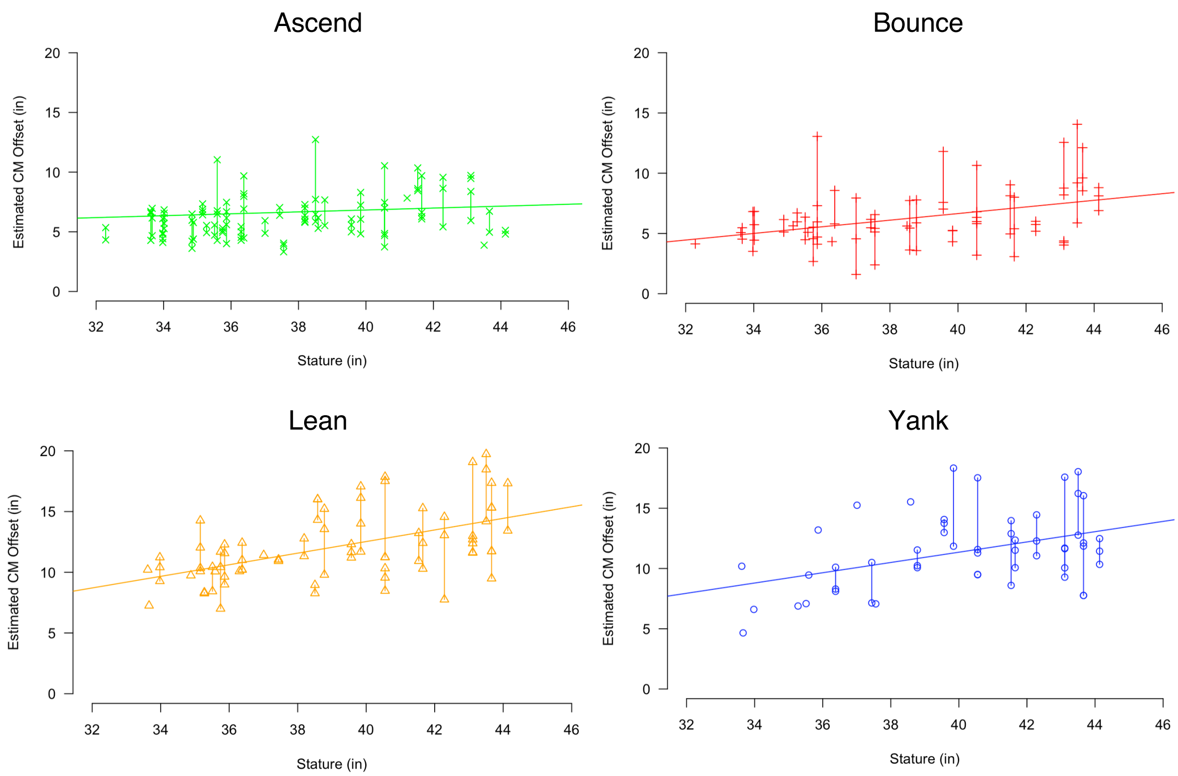


Figure 56. Relationship between estimated CM offset and **stature** for aligned trials for which posture was analyzed.

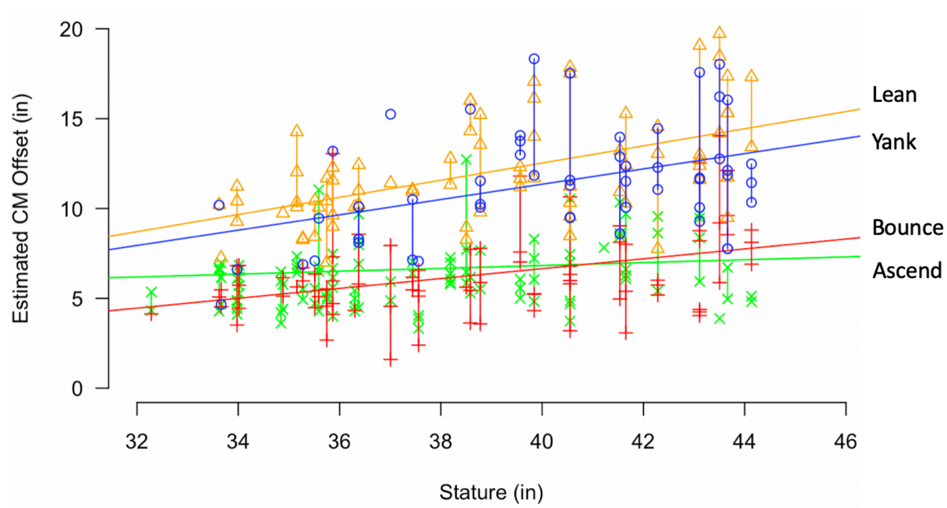


Figure 57. Relationship between estimated CM offset and **stature** for aligned trials for which posture was analyzed (summary across behaviors).

RESULTS: DRAWER AND TABLE TRIALS

Tip-over Moments

The tip-over moment was calculated at three time points in the trials: when the floor vertical force first dropped below 5 N (Ascent), at the point of maximum moment during the trial (Maximum), and at the point where the floor vertical force first rose above 5 N (Descent). Because the child was placed on the simulated table, only descent data are presented for table trials. The maximum moment was generally observed when the child sat or kneeled in the simulated drawer, rather than during ascent. Figure 58 shows sample images from trials at the ascent, peak moment, and descent frames.

Table 22 shows summary statistics for maximum moments calculated for the same virtual fulcrum conditions used for the handle trials, namely fulcrum X = 12 inches and fulcrum Z = 16 inches. Fulcrum X is measured from the front, upper lip (edge) of the simulated drawer or table (see Figure 28).

Figure 58. Example images from ascent, peak moment, and descent frames.

Table 23 shows that normalized moments were generally much lower than for the handle trials. On average, the normalized values were below 1 ft, indicating that the effective center of mass location was inboard of the drawer edge. This is consistent with the design of the fixtures, which necessitated the children to bring their CMs inside the drawer in order to have sufficient stability to leave the floor. On descent, the children controlled their descent to the ground, which again necessitated maintaining the CM over the drawer or table area. Figures 59 and 60 show the relationships with body weight.

Table 22
Summary of Moment Values† for **Drawer and Table*** Trials (lb ft)

Behavior	N	Mean	SD	10th%ile	50th%ile	90th%ile
Ascent	72	28.4	7.5	19.0	28.5	36.6
Maximum	72	37.7	9.3	26.8	36.5	48.7
Descent	89	23.6	9.6	9.4	24.9	35.3

†Moment calculated for 12-inch horizontal virtual fulcrum distance divided by body weight.
* Table trials are included in Descent only

Table 23
Summary of Normalized Moment Values† for **Drawer and Table*** Trials (ft)

Behavior	N	Mean	SD	10th%ile	50th%ile	90th%ile
Ascent	72	0.82	0.16	0.64	0.86	0.98
Maximum	72	1.10	0.26	0.87	1.09	1.29
Descent	89	0.71	0.28	0.30	0.81	0.99

†Moment calculated for 12-inch horizontal virtual fulcrum distance divided by body weight.
* Table trials are included in Descent only

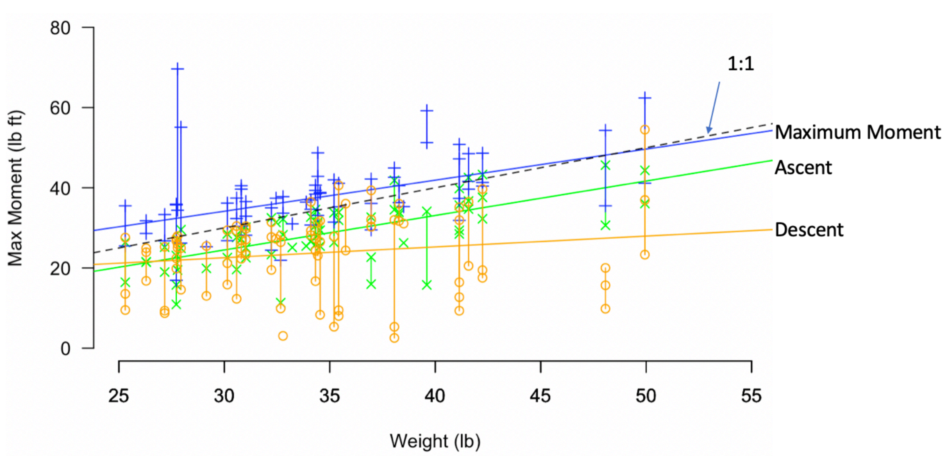


Figure 59. Moment values for drawer and table trials as a function of body weight. Vertical lines connect data from the same subject. Trend lines are shown for each behavior.

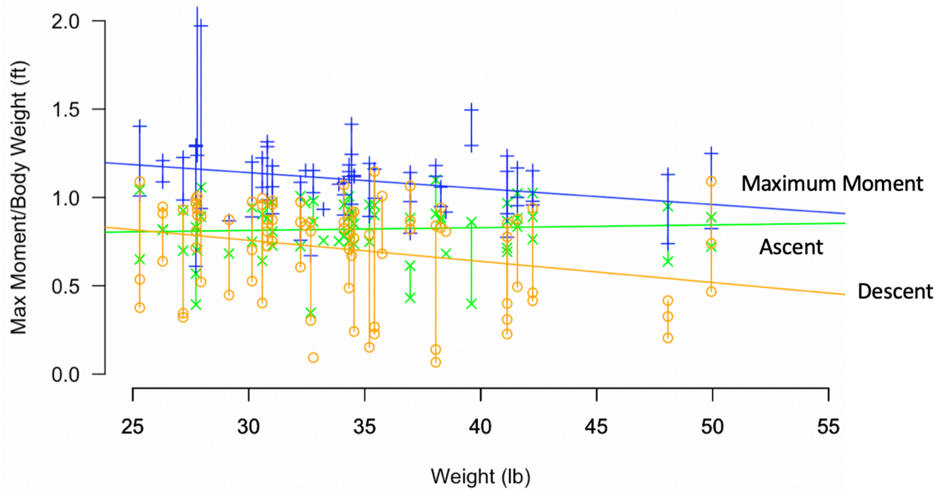


Figure 60. Normalized moment values for drawer and table trials as a function of body weight. Vertical lines connect data from the same subject. Trend lines are shown for each behavior.

Effects of Drawer/Table Height

The height of the drawer affected the moments measured on ascent and descent as well as the peak moment. Figures 61 – 63 show the boxplots of the distributions for each height category. When the drawer was at navel height, the children were able to pivot their torsos over the drawer to a greater extent on ascent, resulting in a smaller moment than when the drawer was higher. The normalized peak moment was also higher when the drawer was at axilla (armpit) height. Figure 64 shows comparative photos illustrating the differences in child posture. The findings for descent were somewhat different. When descending from the highest drawer or table position, most children were conservative and descended backward (facing the drawer/table), leaving their center of mass more centered on the fixture until their first foot touched the ground. Consequently, the normalized moment was larger on average for the lower drawer/table height.

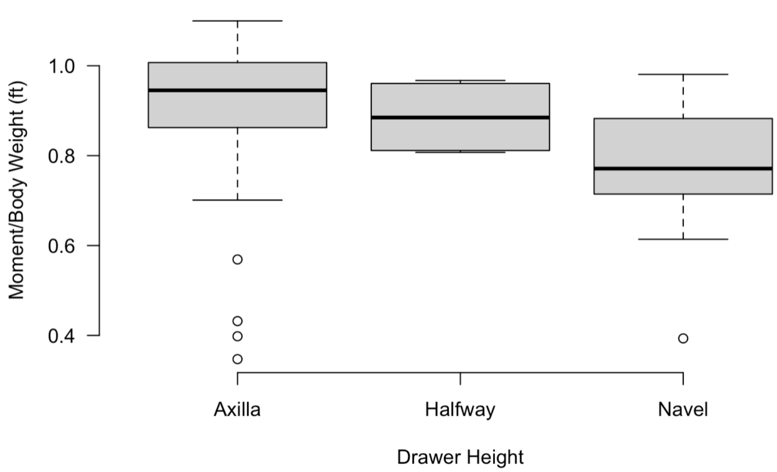


Figure 61. Effect of drawer height on normalized moment on **ascent**.

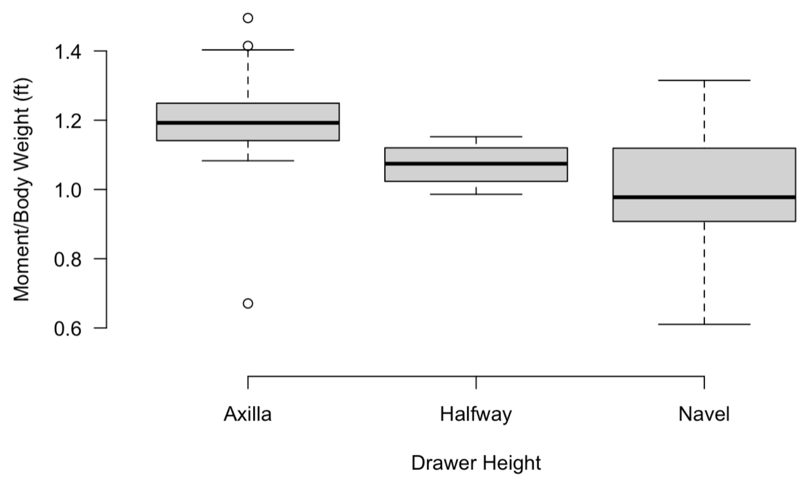


Figure 62. Effect of drawer height on normalized moment at **peak moment**.

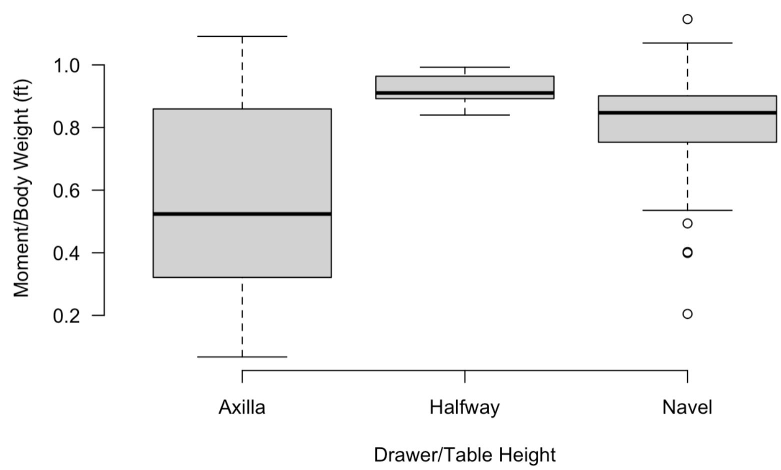


Figure 63. Effect of drawer/table height on normalized moment at **descent**.

Ascent Navel Height	Ascent Axilla Height	Descent Navel Height	Descent Axilla Height

Figure 64. Comparative photos illustrating differences in tactics depending on drawer height.

Jump Descents

In a small number of trials, the child jumped down from the simulated drawer or table. The subset of 33 trials in which the child jumped and apparently landed with both feet on the force plate were extracted for analysis. The mean peak vertical force on the floor was 166 lb (standard deviation 75 lb), an average of 4.7 times body weight. Figure 65 shows the relationship between the peak force and body weight. As expected, children exerted ground reaction forces approximately proportional to body weight, on average, but the effect was weak relative to the variance. All jump landings resulted in forces exceeding two times body weight and some children exerted peak forces exceeding eight times body weight on jump landing. Note that these results are influenced by the foam padding on the floor over the force plate and the children's footwear. Bare feet and thinner or firmer padding would be expected to increase the peak force, as would jump descents from greater height.

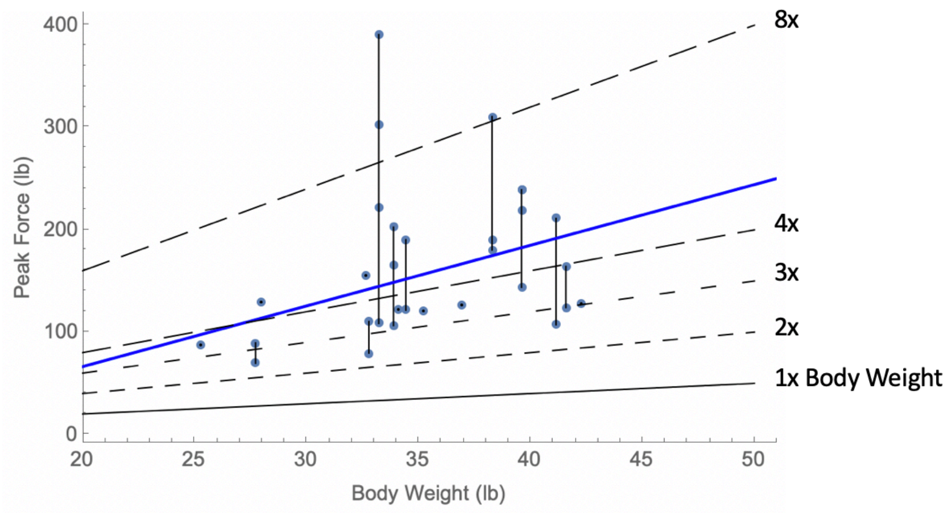


Figure 65. Peak vertical ground reaction force for jump landings as a function of body weight.

Posture Results: Estimated Center of Mass Location

Images from ascent and peak moment frames were manually landmarked as described in the methods section to locate the estimated center of mass (ECM) location. Figure 66 shows sample frames from one trial. For the drawer and table trials, the ECM offset was quantified as the distance outboard (toward the child) from the front upper edge of the fixture. Due to the complexity of the postures relative to the handle-trial postures, the ECM estimates for these trials are considered to be less accurate.

Figure 66. Example digitized frames with estimated center of mass location.

Table 24 lists summary statistics for the ECM offset. Negative values indicate that the ECM was within the drawer or footprint of the tabletop. On average, the ECM was about one inch outboard of the edge when the trailing foot left the floor on ascent and about 2.5 inches outboard when the leading foot reached the floor on descent. This is consistent with the biomechanical considerations.

Figures 67 and 68 show the ECM offset as a function of child body size for the three extracted frames, demonstrating that ECM location is not related to body size in these trials. In general, the tasks are sufficiently constrained geometrically that large body size does not result in differences in average torso location at the selected frames.

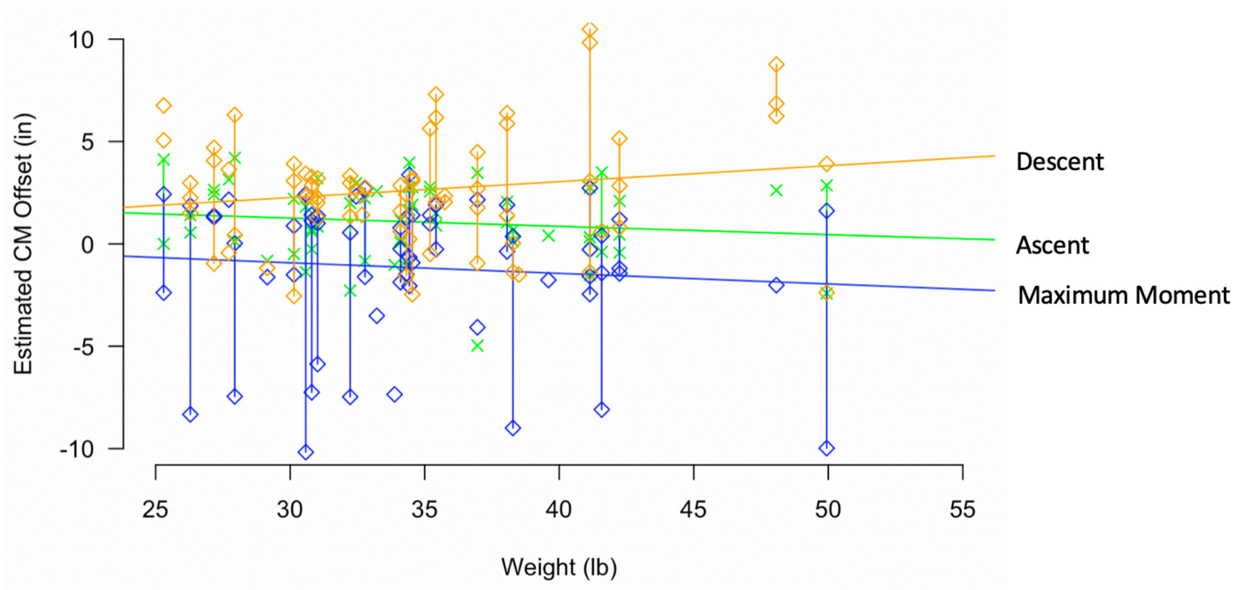


Figure 67. Relationship between estimated CM offset and **body weight** for drawer and table trials for which posture was analyzed.

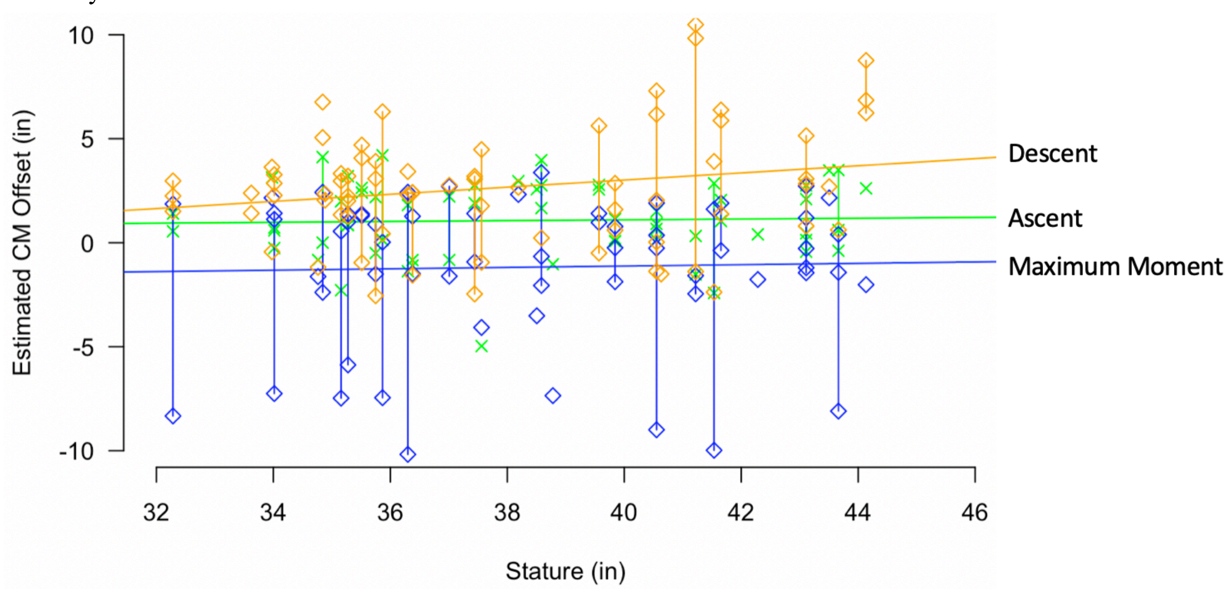


Figure 68. Relationship between estimated CM offset and **stature** for drawer and table trials for which posture was analyzed (summary across behaviors).

The mean ECM values in Table 24 can be compared with the normalized moment values from Table 23 for the same trials and frames. The normalized moment values suggest that the children's CM was in fact inboard of the drawer/table edge on both ascent and descent. The discrepancy with the image-based results is likely due to the fact that the estimated CM location is not valid across all postures and the measurement procedure was based on a single camera view that did not necessarily capture oblique torso postures well. The normalized peak moment values greater than 1 reflect the dynamics of the child dropping into the drawer; the ECM locations for these frames are also within the drawer (negative offset).

Table 24
Estimated Center of Mass Horizontal Offset Outboard of the Front Edge of the Drawer or Table (inches)

Behavior	N Subjects	N Trials	Mean	SD	10thº%ile	50thº%ile	90thº%ile
Ascent	32	61	1.1	1.8	-1.0	0.9	3.1
Maximum	32	61	-1.2	3.5	-7.5	-0.3	2.2
Descent	33	76	2.6	2.7	-1.1	2.4	6.3

Larger CM offsets would be expected to be associated with higher horizontal forces. Figure 69 shows a plot of the upper handle horizontal force (Fx) as a function of ECM offset at the time of peak tip-over moment. The lean and yank behaviors were in some trials associated with horizontal forces nearing or exceeding body weight. These were also generally trials with relatively high ECM offsets, although the scatter in the plot is consistent with the dynamic and variable nature of in these behaviors.

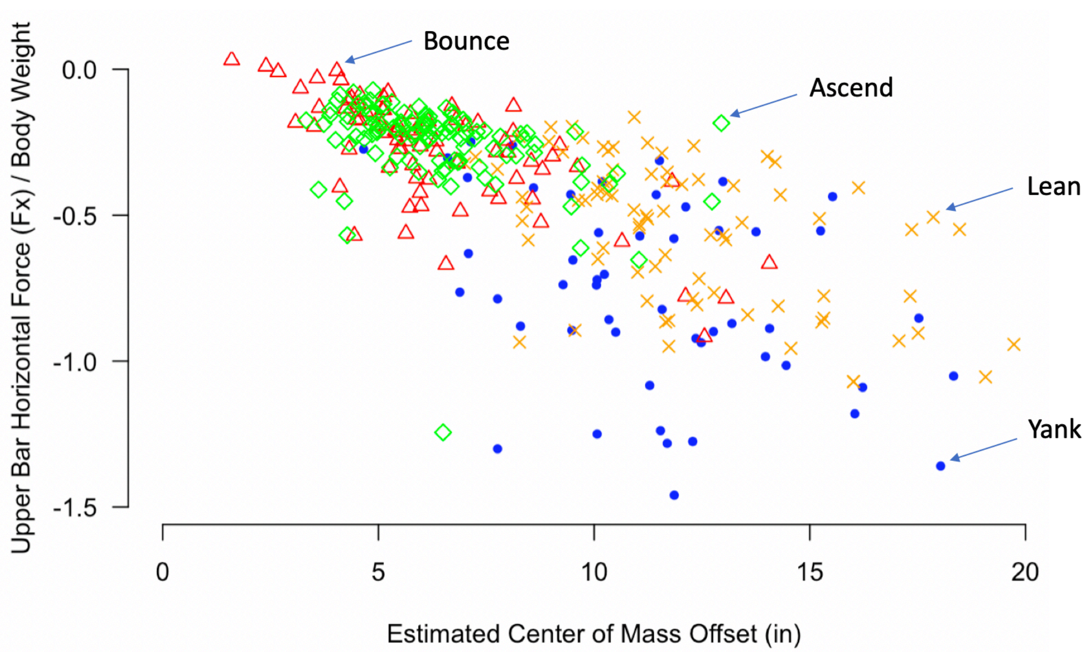


Figure 69. Horizontal force on the upper bar (Fx) normalized by body weight as a function of ECM offset for four behaviors.

RESULTS: SUMMARY

Table 25 and Figure 70 summarize the mean normalized tip-over moments associated with the various child behaviors. When the children were asked to climb in and out of a realistic drawer mockup set to a range of heights, without any reaction surface below it, they produced markedly lower moments than when interacting with separate contact points above the ground during the handle trials. That is, having separate contact points for the hands and feet, with good affordance for exerting force, enabled much greater moment generation. This is due in large part to the ability to support the center of mass outboard of the hands and feet by generating outward horizontal force at the hands and inboard force at the feet. In simple terms, this is the difference between climbing "into" (drawer trials) and climbing "on" (handle trials). To put it another way, the drawer and table trials correspond to interactions of a child negotiating the distance between a single furniture surface and the floor, whereas the handle trials correspond to children who have both hands and feet off of the floor and at different heights.

The results show that a child stepping up (for example, onto an open drawer) while able to grip a surface higher up can exert tip-over moments exceeding body weight by 60% (handle Ascent behavior). In contrast, climbing into a drawer without the ability to hold onto something higher for stability produced lower moments. With good affordance for hand and foot forces, as provided by the handles, children are able to exert moments equivalent to over 3.7 times body weight, on average. Bouncing, without leaning back, can produce average moments over 2.5 times body weight.

Table 25
Mean Normalized Tip-Over Moments Across Conditions (ft)

Behavior – Handle Trials	N	Mean*
Yank	53	3.73
Bounce	82	2.60
LeanBack	83	2.54
1Hand	32	2.18
Ascent	276	1.60
Behavior Frame – Drawer and Table Trials		
Maximum Moment	72	1.10
Ascent	72	0.82
Descent	89	0.71

* Units of ft; may also be interpreted as multiple of body weight exerted one foot from the fulcrum.

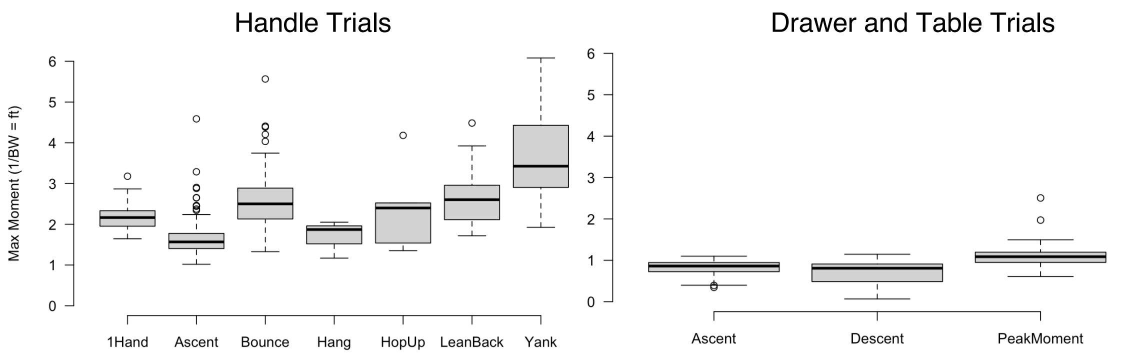


Figure 70. Comparison of the effects of behaviors on tip-over moment across test configurations.

DISCUSSION

Effects of Behavior, Apparatus Configuration, and Child Characteristics on Tip-Over Moments

Child behavior had much stronger effects on tip-over moments than child body size, and behavior influenced the effects of body size. All children were able to perform the Ascent and Bounce behaviors in aligned handle conditions and to climb into the drawer (and descend from the drawer and table) at navel height. Most children were also able to perform the Lean, Yank, and One-hand behaviors, which moved the child's center of mass outward and increased the moments substantially. The apparatus configuration (height of the handles and drawer) had smaller effects than anticipated, in part due to the wide variability among children in their behaviors.

Larger children (heavier or taller) are generally able to exert higher forces and moments, but the effects are generally small relative to the variance among children. The variance is particularly high for the more dynamic activities and those most influenced by body posture (Bounce, Lean, and Yank). The anthropometric effects are larger for behaviors with larger mean responses, indicating that the older, larger, more physically capable children are able to magnify the effects of their body weight through these behaviors (notably Lean and Yank). Given the large residual variance in posture and behavior, further analysis of anthropometric effects is unlikely to be useful; either stature or body weight is a sufficient surrogate for child size and age.

Comparison of Postures and Behaviors with Naturalistic Child Climbing Behavior

Most incidents of furniture tip-over are unwitnessed by anyone other than the child, and far fewer are caught on video. However, online searches readily retrieve videos of children climbing, including some that result in furniture tip overs. Figure 71 shows some images of children climbing to illustrate several characteristics that are similar to the current study:

- Children pull open drawers and use them as steps and handholds.
- Children use other features, such as drawer handles, as affordances for both the hands and feet when climbing.
- Children grasp upper drawers, furniture tops, or other features while stepping on lower drawers.
- When climbing, the children's bodies can be postured such that the center of mass is outboard of the hand and foot locations.

These scenarios demonstrate children exerting both horizontal and vertical forces with their hands and feet, just as they did in the laboratory study. Children are often seen in online videos sitting in drawers into which they've climbed, or on top of dressers and other furniture after climbing.

Limitations

This study has important limitations that should be considered when interpreting the results. The data were gathered in a laboratory environment using fixtures that were specifically constructed to produce idealized boundary conditions. The surfaces the participants interacted with were padded and equipped with high-friction interfaces to ensure that discomfort at the interface would not limit the children's behavior. The fixtures were rigidly mounted, so that no actual tip-over or instability perceptible to the children occurred. The fixtures were not designed to measure the dynamic events during incipient dresser tip overs, such as shifting drawers and a change in the dresser center of mass location with respect to the fulcrum. In general terms, these dynamic changes would be expected to reduce the moment required to continue to move the unit toward tip over.

The analysis focused on peak values of tip-over moment. Peak values of time-series force data are affected by the sampling and filter frequencies. In this case, the low-pass filter frequency of 200 Hz allowed short-duration peaks to be identified. A lower filter frequency would tend to reduce the peak moment. In the complex dynamics of a tip-over event, the mass moment of inertia of the furniture unit would influence the effect of the force exertion time history. The angular impulse generated by the child-exerted forces would impart momentum to the furniture unit. Conceptually, the impulses observed in the current study could be applied to computational models of furniture to estimate the change in momentum. However, the current study was focused on quantification of the child behavior, not the analysis of interactions with actual furniture.

Because the goal of the study was to gather subjective and objective data from children about their climbing behavior, children were recruited who were reported by their caregivers as liking to climb. The extent to which they represent the climbing disposition or tendencies of the general population is unknown. However, all children were reported by their caregivers as within the normal developmental range for their age.

The participants were directed to perform a set of behaviors chosen based on a review of videos of children climbing on clothing storage units and other furniture. These behaviors were within the behavioral repertoire of these normally developing children, except that some children lacked the grip and upper-body strength needed to perform the Hang and HopUp behaviors. The laboratory setting and encouragement from their caregivers may have led the children to engage in riskier behaviors than they would on their own.

Figure 71. Images from publicly available videos of children climbing household items (see Appendix H for a description of search terms). NOTE: visible faces have been blurred.

Further Analysis and Data Gathering

The data from this study could support a variety of further analyses. As noted above, the time histories of force and moments could be used to conduct dynamic simulations of potential tip-over events using realistic furniture characteristics. These calculations could be aided by analyses of the 3D anthropometric and posture data gathered in the study. The body scan data could be used to create 3D, articulated avatars of each child that could be used with the Microsoft Kinect data to track the posture of children more accurately and completely than was done using 2D video in the current project. The center of mass location could be more accurately determined as a function of time from these data.

Additional data could be gathered using similar techniques but more realistic interfaces. The idealized interfaces in the current study were chosen to ensure that they did not create discomfort that might limit child behavior. However, furniture often provides different types of affordances, such as narrow drawer edges and small protruding handles. Future research could investigate the extent to which these features of furniture design influence child climbing behaviors.

REFERENCES

Cusimano, M.D. and Parker, N. (2016). Toppled television sets and head injuries in the pediatric population: a framework for prevention**.** *Journal of Neurosurgery Pediatrics*, 17:3–12

Fryar, C., Gu, Q., Ogden, C., Flegal, K., (2016). *Anthropometric reference data for children and adults: United States, 2011–2014*. National Center for Health Statistics. Vital Health Stat 3.

Gottesman, B.L, McKenzie, L.B., Conner, K.A., and Smith, G.A. (2009). Injuries from furniture tip-overs among children and adolescents in the United States, 1990-2007. *Clinical Pediatrics*. 48(8):851-858.

Nose, T., Kitamura, K., Oono, M., Nishida, Y., and Ohkura, M. (2018). Automatic Learning of Climbing Configuration Space for Digital Human Children Model. In D. N. Cassenti (Ed.): *Proceedings Applied Human Factors and Ergonomics Conference*, AISC 780, pp. 483–490.

Snyder, R.G., Schneider, L.W., Owings, C.L., Reynolds, H.M., Golumb, D.H., and Schork, M.A. (1977). *Anthropometry of Infants, Children, and Youths to Age 18 for Product Safety Design*. Final Report UM-HSRI-77-17. University of Michigan Transportation Research Institute, Ann Arbor, MI.

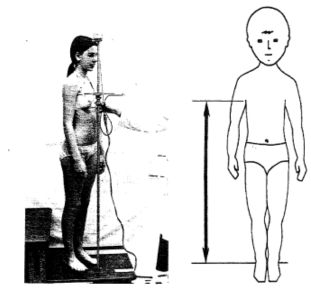
Suchy, A. (2019). *Product Instability or Tip-Over Injuries and Fatalities Associated with Televisions, Furniture, and Appliances: 2019 Report*. U.S. Consumer Product Safety Commission, Bethesda, MD.

Wolf, B.C. and Harding, B.E. (2011). Household Furniture Tip-Over Deaths of Young Children. *Forensic Sciences*, 56(4):918-921.

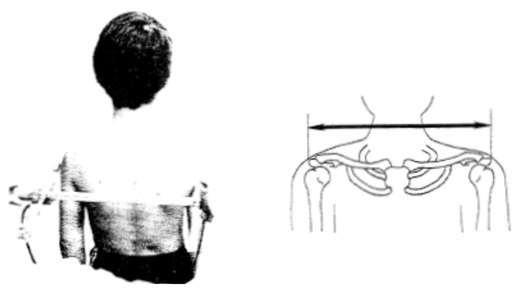
APPENDIX A

Standard Anthropometric Methods

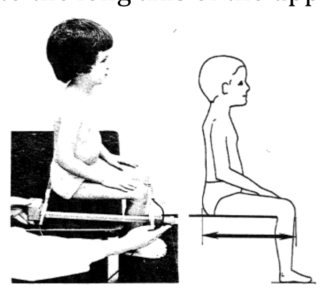
Axilla Height (Snyder 1977)
Subject stands erect, with feet together, weight evenly distributed, arms initially raised then lowered when instrument is in place. With the pointed blade of an anthropometer, measure the vertical distance from the standing surface to the right axilla (armpit).



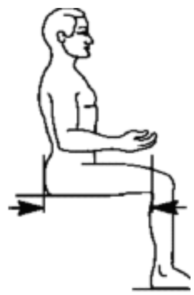
Bi-acromial Breadth (Snyder 1977)
Subject stands erect, arms hanging at sides. With the pointed blades of the anthropometer, measure the horizontal distance between the most lateral edges of the right and left acromion landmarks. (*Make sure shoulders are in widest position)*



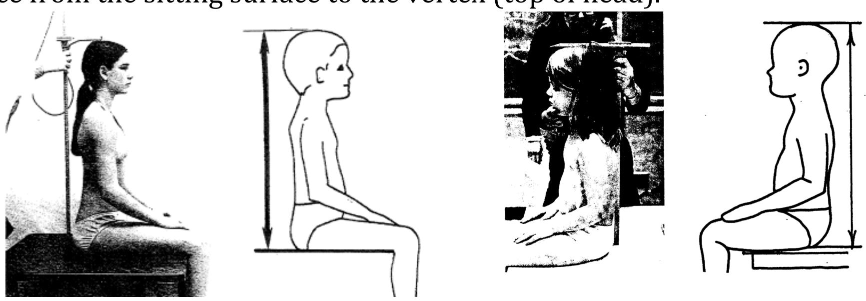
Buttock-Knee Length (Snyder 1977)
Subject sits erect, feet resting on a platform adjusted for 90° knee flexion. With the paddle blades of an anthropometer, measure the distance from the posterior surface of the right buttock to the anterior surface of the knee parallel to the long axis of the upper leg.



Buttock-Popliteal Length (ANSUR II)
The horizontal distance between a buttock plate placed at the most posterior point on either buttock and the back of the right knee (the popliteal fossa at the dorsal juncture of the calf and thigh) is measured with an anthropometer. The subject sits erect. The thighs are parallel and the knees flexed 90° with the feet in line with the thighs.

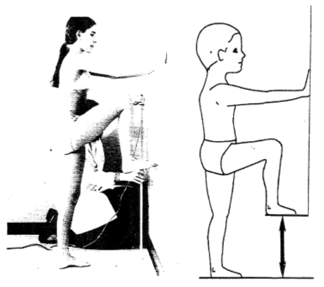


Erect Sitting Height (Snyder 1977)
Subject sits erect with head oriented in the Frankfort Plane (tragion to infraorbitale level), arms hanging at sides, hands resting on thigh. With the paddle blade of the anthropometer, measure the vertical distance from the sitting surface to the vertex (top of head).

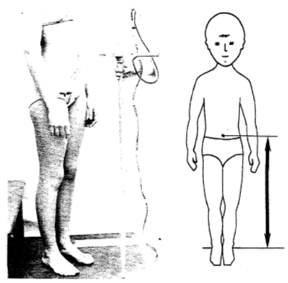


Hip Breadth (Snyder 1977)
Subject sits erect with knees together, feet resting on a platform adjusted for 90° knee flexion. With the paddle blades of an anthropometer, measure the maximum breadth across the hips parallel to the seated surface.

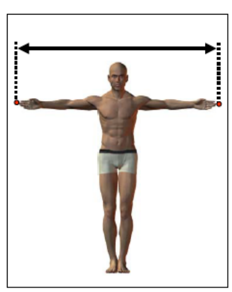
Max Step Height (Snyder 1977)
Subject stands erect facing wall with palms of hands resting lightly against wall at shoulder level for balance. Subject raises right foot to maximum height from floor. With the paddle blade of an anthropometer, measure the vertical distance from the floor to the ball of the foot.



Omphalion Height (Snyder 1977)
Subject stands erect with feet together and weight evenly distributed. With the pointed blade of an anthropometer, measure the vertical distance from the standing surface to the umbilicus (navel).

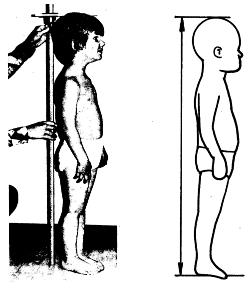


Span (Reach) (ANSUR II)
The distance between the tips of the middle fingers of the horizontally outstretched arms is measured on a wall chart. The participant stands erect with the back against a wall-mounted scale and the heels together. Both arms and hands are stretched horizontally along the wall with the tip of the middle finger of one hand just touching a side wall. A block is placed at the tip of the middle finger of the other hand to establish the measurement on the scale. The measurement is taken at the maximum point of quiet respiration.

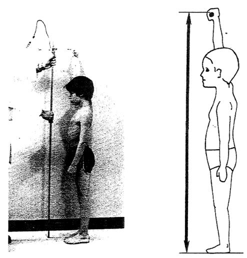


Stature (Snyder 1975)
Subject stands erect with head oriented in the Frankfort Plane (tragion to infraorbitale level), arms hanging at sides. With an anthropometer, measure the vertical distance from the standing surface

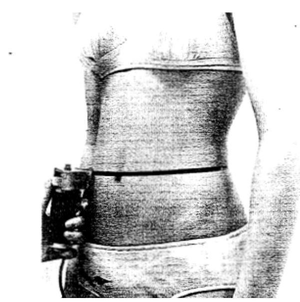
to vertex (top of the head).



Upward Grip Reach (Snyder 1977)
Subject stands erect with feet together, left shoulder against wall, grasping the handle of the grip device in right hand, and abducts extended right arm to maximum horizontal grip reach. With the pointed blade of an anthropometer, measure the horizontal distance from the wall to the most distal point on the handle of the grip device.



Waist Circumference, Omphalion (Snyder 1977)
Subject stands erect with feet together, weight evenly distributed, and arms hanging at sides. With a tape device, measure the horizontal circumference of the waist during normal breathing at the level of the umbilicus (navel).



APPENDIX B
Standard Anthropometric Data

Participant Number	Gender	Age (mo)	BMI (kg/m^2)	Weight (kg)	Stature (mm)	Axilla Height (mm)	Omphalion Height (mm)	Upward Grip Reach (mm)	Max. Step Height (mm)
CP05	F	31	15.4	12.6	904	595	477	983	235
CP06	M	65	15.6	19.5	1117	768	635	1310	316
CP07	F	50	15.1	16.1	1030	755	592	1154	332
C001	F	60	13.7	16.8	1105	782	635	1256	376
C002	F	54	15.3	18.9	1109	800	642	1322	321
C003	M	29	15.6	14.75	970	667	516	1054	208
C004	F	51	15.1	15.5	1012	734	589	1172	356
C005	F	47	20.3	22.7	1055	777	601	1255	304
C006	M	21	18.7	14	864	566	446	921	259
C007	F	58	15.4	17.3	1058	769	622	1200	289
C008	F	35	18.2	15.6	924	659	507	1037	215
C009	M	42	15.8	16	1005	711	564	1160	391
C010	M	36	18.4	16.8	954	635	487	1078	240
C011	M	46	16.4	17.5	1032	715	575	1158	293
C012	F	30	17.1	12.5	855	595	459	1050	209
C013	M	23	17.7	11.95	820	567	424	963	230
C014	M	32	14.6	11.5	885	705	526	1025	256
C015	M	65	15.6	18	1074	773	618	1262	240
C016	F	27	16.9	13.25	883	587	463	998	221
C017	M	41	16.2	15.65	980	724	529	1125	283
C018	F	28	18.3	14.65	893	629	472	1022	231
C019	F	42	16.6	13.7	908	638	476	1020	225
C020	M	48	17.0	18.7	1047	749	580	1200	320
C021	M	54	15.8	15.4	985	702	555	1130	221
C022	M	22	20.3	14.85	854	602	431	953	183
C023	F	29	15.3	12.7	911	675	513	1060	201
C024	F	20	18.3	13.6	860	603	438	965	175
C025	M	28	17.5	14.1	896	637	473	996	186
C026	F	56	15.5	18.7	1095	802	622	1256	402
C027	F	35	15.1	12.35	902	627	483	978	300
C028	M	57	16.0	19.2	1095	805	637	1211	365
C029	F	38	16.3	13.9	922	671	516	1027	291
C030	F	33	17.3	15.7	951	701	506	1126	278
C031	M	29	16.9	12.6	863	594	450	971	213
C032	F	21	18.6	10.3	743	546	391	823	190
C033	M	42	15.7	15.1	978	735	544	1117	275
C034	F	57	16.4	17.4	1030	743	586	1165	272
C035	M	38	16.8	14.9	940	660	504	1035	225
C036	M	52	17.3	21.85	1121	800	628	1282	305
C037	M	23	20.7	16.25	886	623	481	1006	262

Participant Number	Gender	Age (mo)	Waist Circumference at Omphalion (mm)	Erect Sitting Height (mm)	Hip Breadth (mm)	Buttock-Popliteal Length (mm)	Buttock-Knee Length (mm)	Biacromial Breadth (mm)	Reach Span (mm)
CP05	F	31	555	511	190	219	292	215	Null
CP06	M	65	555	608	233	312	363	253	1092
CP07	F	50	565	566	206	275	334	228	1004
C001	F	60	498	612	212	290	351	230	1028
C002	F	54	565	604	217	284	356	252	1060
C003	M	29	578	548	190	237	333	225	971
C004	F	51	503	560	200	251	326	231	986
C005	F	47	652	578	243	293	360	252	1104
C006	M	21	509	512	204	222	264	223	851
C007	F	58	540	589	210	274	339	243	1000
C008	F	35	520	543	207	230	301	214	890
C009	M	42	515	585	207	311	259	219	973
C010	M	36	561	548	213	237	309	225	900
C011	M	46	Null	Null	Null	Null	Null	Null	1016
C012	F	30	480	521	182	221	277	213	768
C013	M	23	510	510	188	189	260	204	762
C014	M	32	458	511	171	Null	284	212	Null
C015	M	65	524	591	199	351	307	233	1014
C016	F	27	512	481	200	278	231	210	820
C017	M	41	502	577	185	224	303	224	964
C018	F	28	535	536	188	221	286	225	857
C019	F	42	530	515	195	230	297	198	807
C020	M	48	532	618	212	260	320	239	1021
C021	M	54	512	542	207	274	321	233	990
C022	M	22	534	505	198	223	265	221	Null
C023	F	29	495	514	181	229	289	219	885
C024	F	20	532	515	233	234	284	190	844
C025	M	28	529	546	190	226	277	206	825
C026	F	56	557	604	223	293	357	245	1060
C027	F	35	500	535	188	221	278	216	859
C028	M	57	515	615	220	277	357	256	1050
C029	F	38	490	556	183	229	289	208	861
C030	F	33	516	584	207	234	296	212	863
C031	M	29	510	527	268	226	184	204	848
C032	F	21	490	468	170	196	249	193	714
C033	M	42	475	550	180	254	307	215	929
C034	F	57	562	601	213	284	342	222	942
C035	M	38	517	550	202	253	300	214	867
C036	M	52	540	650	234	270	354	271	1100
C037	M	23	551	545	224	213	277	228	851

APPENDIX C

Focus Group Structured Protocol

Furniture Questionnaire CPSC Dresser
Revision 2019-10-02 Participant Number__________________

PARENT QUESTIONS

[Administered orally by research assistant, responses recorded by hand. Parent questions are administered while the child is being measured (standard anthropometry) in the same room.]

1. Has your child shown an interest in climbing on a household item (not on a playground)? **Y N**

2. What was the item, where was it located and how did he/she climb?
   What:
   Where:
   How:

3. Does the child have furniture for clothing storage (for example a dresser) in their room? **Y N**
   a. If no: Do they have access to furniture like that in the house?

4. Have you observed your child interacting with the dresser [or whatever word the caregiver uses]? **Y N**

5. How does/did your child interact with the furniture (e.g. climbs, opens drawers, pulls items out of drawers, sits in drawers)?

6. If the child climbs/climbed on the furniture, what strategy is used (e.g. all drawers closed, drawers opened in a staggered pattern, uses other objects or furniture)?

7. How does/did the child get down from the furniture?

8. Does/did the child interact similarly with other furniture items (e.g. nightstands, media units, accent/occasional furniture, office furniture, bookcases)? **Y N**

9. Do you have anything else that you would like to mention? Are there any issues that we have not raised?

CHILD QUESTIONS

[Administered orally by research assistant, responses recorded by hand. Child questions are administered with the parent in the same room.]

10. Do you like climbing? **Y** **N**

11. What types of things do you climb?

12. How do you climb?

13. For the items identified by the parent: What do you do with the [furniture item]? (e.g. open the drawers, get things out, stand/sit/climb on the item) NOTE: Do not prompt for sit/standing/climbing unless raised by the parent or child.

14. If there is something in or on the item that is hard to reach, how would you try to get it?

APPENDIX D

Scripted Instructions

Consent Scripts

Research Assistant to Adult:

Thank you for volunteering today. Before we start I would like to go over what we are doing today and answer any questions you may have. We will measure your child's body dimensions and record his or her weight. We will use special rulers called anthropometers to take these measurements and will need to touch your child's head, chest, pelvis, arms and legs. We will also record your child's body shape using a whole-body surface measurement system. This system uses a red laser light similar to the light used in a supermarket checkout scanner. This system is in a laboratory down the hall.

Most of the time during this session we will ask your child to climb onto a low bar while pulling on a handle, as if climbing on playground equipment. We will ask him/her to lean back and pull as hard as he/she can. We will start with asking your child to climb into and out of this box that simulates a piece of furniture.

We will record three-dimensional video of your child as he or she is participating in the study. We need the video to understand how your child performs the tasks. Video recording is required to participate in the study.

You will stay with your child at all times during the study. You are free to leave the study at any time. We will take little breaks during this session. Please let us know if you think your child needs a break, or if you have any questions during testing.

Research Assistant to Child:

We want to know how you are. We want you to push and pull (*demonstrates*) on handles as hard as you can. We want you to climb. We will show you how. Your (dad or mom) has said that it is OK.

Do you want to do this?

[Require oral yes.]

Anthropometry Script

We are going to do some measurements with rulers now and some later.

To child: I am going to see how big you are now.

<u>*Weight*</u>

To Child: Please take off your shoes.
Step on this scale. Hands at your sides.

<u>*Stature*</u>

To parent: Please stand in front of your child.

To Child: Stand here (*2 feet in front of parent*). Look at your mom/dad. I am going to touch the top of your head.

<u>*Omphalion Ht*</u>

To Both: We are going to do that again. Except I will measure to your belly button.

<u>*Axilla Ht*</u>

To Both: We are going to do that again. Except I will measure to your armpit.

To Both: I am going to take some arm and leg measurements.

<u>***Max Step Height***</u>

To Child: Stand facing this corner. Right hand on this wall. Arm straight. Stand straight.

To Parent: We are measuring maximum step height. Please keep your child standing straight. His/her hand is on the wall for support. He/she will lift the right leg. Please help your child hold the knee bent and foot flat at the highest point.

(show illustration if needed)

<u>***Overhead reach***</u>

To Child: Stand in this corner. Face this way. Back and legs against this wall. Hold this piece of wood.

To Parent: We are measuring overhead reach. Please keep your child standing straight. His/her back and heels against the wall. Feet flat on floor. Please help your child bring his/her arm up so that the wood is flat on the wall.

(show illustration if needed)

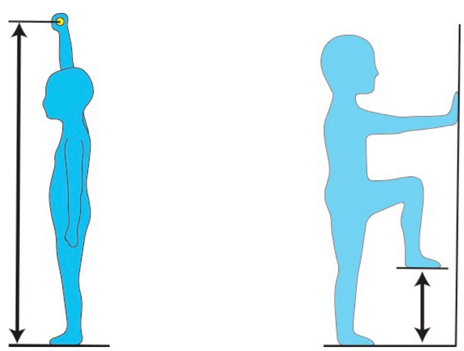


Figure D1: Illustration shown to parent before overhead reach and maximum step height measurements

General Instruction Script

I am going to set up the equipment in different ways. NN (*name of investigator*) is at the computer and will check that the equipment is working properly (*zeroing)* each time I make a change. It is important that while NN is checking --- no one stand on this square or touch this equipment. When I make changes, I may ask both of you (*parent and child*) to stand in the lower area with the door closed. This will ensure that your child is not around the equipment while it is moving.

Drawer Conditions Script

To Parent:

This box represents a furniture drawer. I am setting the top edge of the drawer at your child's belly button height. I will ask him/her to crawl in, wait a moment, and then crawl out.

Please watch your child while you stand here *(show spot not in way of Kinects or camera – near "X" on floor)*. We would like to get his/her behavior without your help. However, if you think that 1) your child is stuck and can't go up or down or 2) is about to fall from a height that you do not feel comfortable with, please step in and take your child off of the equipment.

To Child:

Sit here on this tape.

(Start Recording)

I am putting this silly toy in here. (*if needed with younger child)*

Please climb into the box. *Alternates:* Go sit in the box. Go sit next to toy.

(*When they are inside)*

Sit down.

Please hand me the toy. (*if needed with younger child)*

Now climb out of the box. *Alternates:* Go sit on "X"/next to parent. I will hold your toy.

Go sit on the tape. *Alternates:* Go by mom/dad/toy.

To Parent:

I am going to raise the height of the edge to be half way between your child's belly button and armpit height (*or at armpit height, or lower)*. And he/she will crawl in, wait a moment, and then crawl out. If this is too hard for your child I will lower it a bit. If this is very easy for your child I will raise it a bit.

Table Conditions Script

To Parent:

This represents the top of a table or dresser. We are going to measure your child as he/she gets themselves down from the top. I would like you to place your child so he/she is sitting on top of it. Your child should **<u>not</u>** stand up on the top. Please do not stand on the square on the floor after you have placed your child on the table top.

Please watch your child while you stand here *(show spot)*. We would like to get his/her behavior without your help. However, if you think that 1) your child is stuck and can't go up or down or 2) is about to fall from a height that you do not feel comfortable with, please step in and take your child off of the equipment.

To Child:

Sit here on this tape. *(Start Recording)*

To Parent:

Please place your child on the top

To Child: (*When they are on top)*

(If they look like they are going to stand) ... Sit down on your bottom.

Climb down. *Alternates:* Go by mom/dad/toy.

Go sit on the tape. *Alternates:* Go by mom/dad/toy.

Note: The initial position of their legs might be different: over the edge versus cross legged. If you have time and the child is willing, do a second trial with whichever they did not do the first time.

Dresser Conditions Script

To Parent:

These two bars represent the front of a piece of furniture a child might climb. We are going to move the bars to two different heights and in and out. Each time we move them, we will need to make sure they are working properly, so we need to stand away from the square.

We will then ask your child to step onto the lower bar and hang onto the top bar with their hands. We have a list of things we would like your child to do while standing on the lower bar. We may not ask him/her to do all of them every time.

To Child:

Sit here on this tape.
See definitions of actions below

Climb up: Climb up on the step. Hand on handle.
(Both hands and feet should be on the bar after completion)
Alternate:

1) Feet here. Hands here. (point to each bar)
2) *Use hands to show up stepping motion*
3) *Practice when not collecting, guiding hands and feet.*

Bounce: *Practice on floor before going on the step.*
Keep feet touching lower step. Bounce up and down. Use your arms and legs to bounce.
(feet should stay on the step)
Alternate:

1) Jump high! Jump again! Now keep your feet on floor. *(hold feet with hands)*
2) Squish down low. Jump up. *(hold feet with hands)*
3) Down, down, down! >>> Up, up, up! *Other pairs:* tiny/big!
4) Boing-y! Boing-y!
5) *When demonstrating emphasize being tiny and then rocketing up. Explosive!*

Lean Back: Lean back as far as you can. Straight arms and legs. *(pause ... then go to "Yank")*
(after they are in the position for a moment)
Alternate:

1) *Practice while on the bar, but not recording - help them lean backwards while on bar.*
2) Hang on! Feet stay. Body away.

Yank: Yank/Pull as hard as you can on the handle.
Alternate:

1) *Practice while on the floor: take child's hands and do a push-me, pull-you type of game*
2) Shake the handle. Shake, shake, shake! *Other word:* Rattle

1 Hand and 1 Foot: Take one hand off the handle. Take one foot off the step.

(correct if not the same side of body by saying ...)

Now switch legs.

A*lternate:*

1) *Stand behind child and ask them to touch your hand with their hand. Then their foot.*
    a. Hang on. One hand here / high five. This foot (point to same side foot) here.
2) *Practice while on the bar, but not recording - help them let go of bar and move foot*
3) Hang on … *(touch hand)* ... Hand please … *(touch foot with other hand)* ... Foot please.

Hop Up: Stand on the floor here (point to spot). Do not use the step (shake head).
(pause) Hands on handle.
(if low or mid bar) Hop up so your tummy touches handle. Keep tummy on handle.
(if highest bar) Do a pull up.
Drop down to the floor (point to floor). *If needed*>> No landing on step!

A*lternate:*

1) Hop up like you are getting out of a pool.
2) Super jump! Use handle to help you get higher.
3) Jump high. Handle helps you get higher!

Hang: Stand on floor … (point to spot) … Hands on handle … ***(pause)***
Hang. Feet off floor. Drop to the floor.

(ONLY hang in WR -- offset conditions)

Climb down: (*Make sure they are back in a "standard" 2-foot, 2-hand posture before starting).*

Please climb down.

A*lternate:*

1) Feet here. (point to floor)
2) *Use hands to show down stepping motion.*

If you need to act it out, stand on the child's left side. Sometimes standing beside the child is helpful when showing a fore-aft motion such as lean or yank as it is hard to mirror that.

APPENDIX E

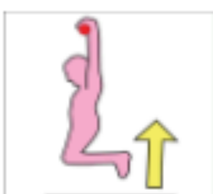
Illustrated Instructions for Handle Conditions

Bounce

Lean Back

Yank !!!

1 hand + 1 foot

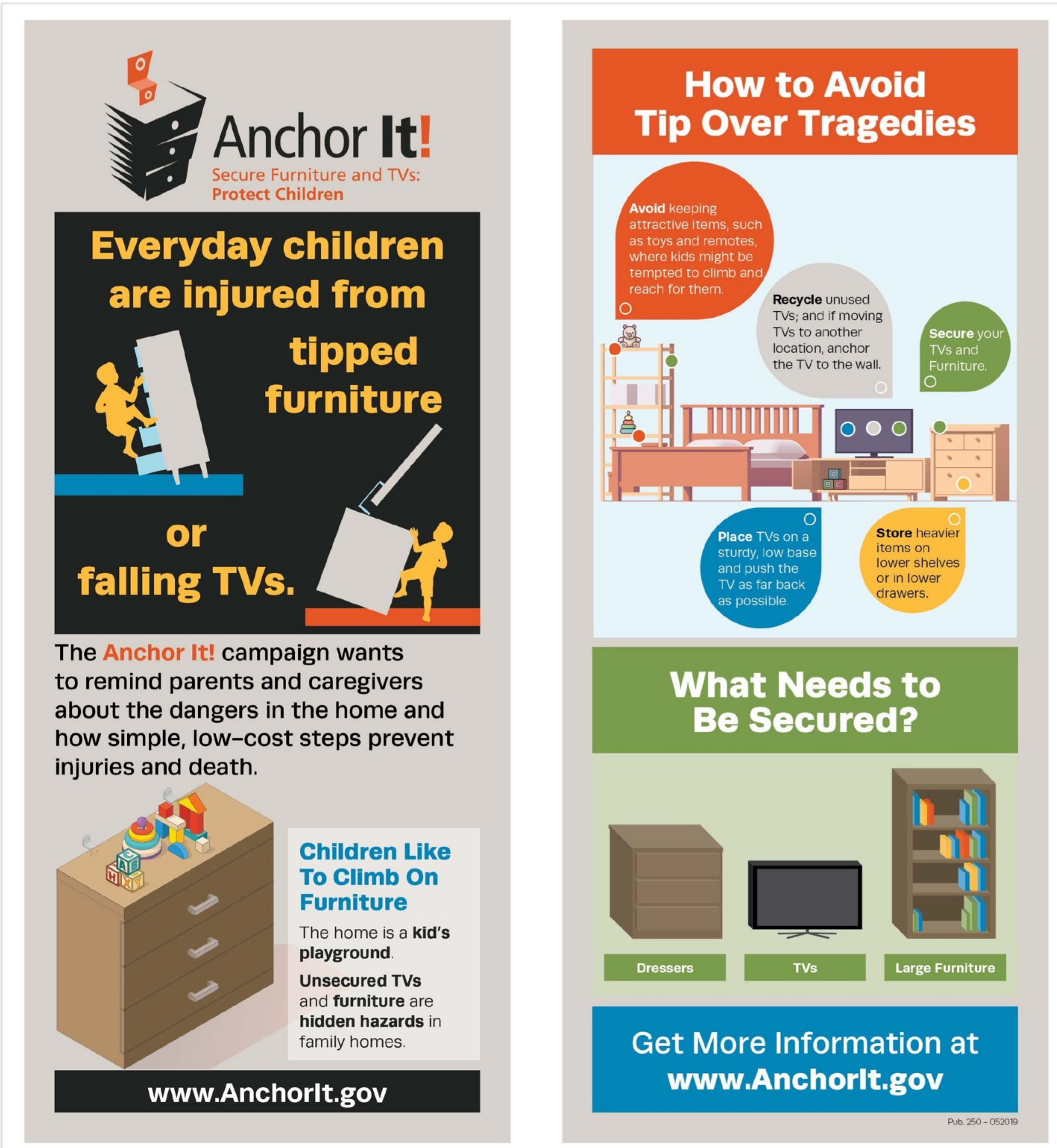


Hang

Hop Up

APPENDIX F

Tip-Over Safety Handout



APPENDIX G

Focus Group Responses

Table 1
Caregiver Answers, Part 1

Participant Number	Age at Testing (mo)	Has your child shown an interest in climbing on a household item?	What was the item?	Where was it located?	How did he/she climb?
CP05	31	Yes	table; fridge; tub; dresser; couch; play kitchen; computer desk; metal drawers in pantry	kitchen; living room; bathroom	move to chair; climb on back of couch
CP06	65	(no response)	stair rails; window ledges; trees	(no response)	(no response)
CP07	50	Yes	coffee tables; couch back; kitchen table	living room; kitchen	hands to pull up, knee on couch; gets on chair
C001	60	Yes	couch; bathroom towel rod	family room; bathroom	jumping on/off; hanging (broke); uses stepstool
C002	54	Yes	couch	living room	jumped up
C003	29	Yes	chairs; bar stool chair; sofa	kitchen; living room	elbows/knees; jumps off
C004	51	Yes	window	living room	small child chair into window sill standing
C005	47	Yes	stairwell; dresser; desk; counters	bannister; parents' room; computer room; kitchen	pulling; used chair; barstool
C006	21	Yes	couch; coffee table; kitchen table; stairs	(no response)	couches at first, then becomes daredevil
C007	58	Yes	couch; ladders; stairs; counter top; dressers	mom's room	object sitting near dresser that she used to climb up there
C008	35	Yes	couch (no furniture except couches)	living room	climb
C009	42	Yes	chair; bed; couch	living room; bedroom	hands & knees
C010	36	Yes	couch; countertop; crib (in & out); beds	living room; kitchen; bedroom; parents' room	standard; step stool; leg up; pulls sheets & blankets
C011	46	Yes	table; desk; bookshelf; bed; couch	living room; basement; bedroom	hands & feet
C012	30	Yes	table; hang from chandelier/light	dining room	chair to table
C013	23	Yes	train table; end table; stool; couches; bed; bench	basement; kitchen; living room; parents' room; entry	hands and feet; with plastic stool
C014	32	Yes	everything; stairs; shelves; dressers; couch; bed	(no response)	hands & feet
C015	65	Yes	sofa; parents' bed; bathtub	living room; bedroom; bathroom	hands & feet
C016	27	Yes	sofa; parents' bed; stairs	living room; bedroom	climbs hands & feet; uses step stool for sink to hold onto the counter
C017	41	Yes	beds; couches; chairs; tables; cubes; baby gates; brick hearth; stairs	bedrooms; living room; kitchen; coffee table; hall	uses objects to step up - whatever is there
C018	28	Yes	beds; couch; brick fireplace; chairs; basement stairs	bedroom; living room; kitchen	grab and pull up

C019	42	Yes	couches; tables; bed; coffee table; kitchen/office chairs	living room; kitchen; bedroom; office	leg over; chair to table; step on frame, leg over, pulled up; climbs from floor; pull up from belly, leg over
C020	48	Yes	dressers; couch back (sectional); coffee table; bunkbed ladder	bedroom; living room	hands & feet (handles) or from bed to dresser; flip over back of arm, floor to cushions to back
C021	54	Yes	counters; dressers; couch; coffee table; bunkbed ladder	kitchen; bedroom; living room	stool/chair; climbs handles or from bed to dresser; flip over back of arm or floor to cushions to back; hands & feet
C022	22	Yes	couch (back); coffee tables; chairs; crib	living room; dining room; bedroom	flop; pull up; hanging on bar
C023	29	Yes	dresser; bunk beds; pantry shelves; cabinets; window; table	bedroom; pantry; kitchen; living room; dining room	pulling out drawers; rail; swing up
C024	20	Yes	couch; chair; bench seat	living room; dining room	knee up; reaches across and pulls herself up
C025	28	Yes	bed; crib; changing table; desk; coffee table; table; book case	bedroom; parents' room; living room; kitchen	steps on trundle, pulls up; base of crib; nightstand; chair; arms
C026	56	Yes	couch; bed; counter; tables; window sill; toilet	living room; bedroom; kitchen; anywhere; bathroom	hands, feet; kid chair; kitchen chair; step up, pulls up
C027	35	Yes	counter; table; couches; beds	kitchen; living room; bedroom	(no response)
C028	57	Yes	toy organizer; dresser; cabinet; table; counter	living room; parents' room; kitchen	ladder style
C029	38	Yes	table; ladder; playground	kitchen	chair
C030	33	Yes	couch; table; crib; beds	living room; dining room; bedrooms	knees up - hands & knees
C031	29	Yes	coffee table; couch; dining table; beds (can't get down)	living room; dining room; bedroom	hands & feet; chair to table; shimmies up
C032	21	Yes	stool; table; ottoman (high)	play room; living room	front first, flop & scoot
C033	42	Yes	couch; changing table; mantle; chairs; dining table; counter	living room; entryway; dining room; kitchen	sit/walk across back; swing leg up boxes, bin; step up; chair
C034	57	Yes	counter; bunk bed ladder; couch; bed	kitchen; bedrooms; living room	stool, props herself up and jumps; hands & feet; puts leg up & pulls up; pulls up & swings leg over
C035	38	Yes	counter; bunk bed ladder; couch; bed	kitchen; sister's room; living room; bedroom	hands & feet; leg up & pull; pulls up & swings leg over
C036	52	Yes	couch; ottoman; pool table; chairs	living room; family room	leg up; hop up
C037	23	Yes	couch; chair; ottoman; book shelf; coffee table	living room	leg up; elbows, feet

Table 2
Caregiver Answers, Part 2

Participant Number	Age at Testing (mo)	Does the child have furniture for clothing storage in their room?	If no, do they have access to furniture like that in the house?	Have you observed your child interacting with the dresser?	How does/did your child interact with the furniture?
CP05	31	Yes	N/A	Yes	Dump out, stool, move chair
CP06	65	(no response)	(no response)	(no response)	(no response)
CP07	50	Yes	N/A	Yes	opens drawers, pulls clothes out
C001	60	Yes	N/A	Yes	opens/closes to get clothes out
C002	54	Yes	N/A	Yes	opens & closes
C003	29	Yes	N/A	Yes	opens drawers, empties
C004	51	Yes	N/A	Yes	opens drawers, pulls items out, when she was little
C005	47	Yes	N/A	No	N/A
C006	21	Yes	N/A	Yes	open & close drawers; does not climb
C007	58	Yes	N/A	Yes	appropriately
C008	35	Yes	N/A	Yes	opens drawers, gets clothes out
C009	42	No	Yes - parents' room	No	N/A
C010	36	Yes	N/A	Yes	opens & closes drawers; clothes in bottom & top drawer - used to climb on bed and lean over to get stuff out of top drawer
C011	46	Yes	N/A	Yes	opening
C012	30	No	No	No	not interested
C013	23	Yes	N/A	No	opens bottom drawer
C014	32	Yes	N/A	Yes	opens drawers, takes clothes out
C015	65	Yes	N/A	Yes	opens drawers, takes clothes out, closes drawers
C016	27	Yes	N/A	No	ignores it
C017	41	Yes	plastic 3-tiered	Yes	takes drawers, dumps clothes - no climbing, sits in drawers under bed
C018	28	Yes	plastic 3-drawer	Yes	pull out drawers and dump things
C019	42	Yes	N/A	Yes	opens drawers for clothes - doesn't sit in, hasn't recently climbed on/in it
C020	48	Yes	N/A	Yes	climbs, opens drawers to take clothes out
C021	54	Yes	N/A	Yes	climbs; opens drawers to get clothes out
C022	22	Yes	N/A	Yes	getting things from top (no climbing)
C023	29	Yes	N/A	Yes	opens drawers, stands in bottom, climbs to middle
C024	20	Yes	N/A	No	Yes - opens drawers on dresser
C025	28	Yes	N/A	Yes	opens & shuts drawers; pulls stuff out
C026	56	Yes - 5-drawer square cubby	N/A	Yes	only allowed to open and close; foot on cubby, dresser bolted to wall; uses step stool
C027	35	Yes	N/A	Yes	Yes - 2-tier dresser in closet - on top are clothes hung. Climbed onto storage box and then onto dresser to get the dress she wanted
C028	57	Yes	N/A	Yes	since 18 months
C029	38	Yes	N/A	Yes	clothes in & out; opens & closes doors
C030	33	Yes	N/A	Yes	opens drawers - gets out clothes
C031	29	Yes	N/A	Yes	opens/shuts, fills with books, takes out clothes
C032	21	Yes	N/A	Yes	tries to put things in drawers
C033	42	Yes	N/A	Yes	opens drawers; climbed - stepping into drawer
C034	57	Yes	N/A	Yes	climbed once - tipped over (didn't see); opens & shuts drawers

C035	38	Yes	N/A	Yes	opens & closes drawers
C036	52	Yes	N/A	Yes	opens drawers; pulls items out of drawers
C037	23	Yes	N/A	Yes	opens drawers pulls items out of drawers

Table 3
Caregiver Answers, Part 3

Participant Number	Age at Testing (mo)	If the child climbs/climbed on the furniture, what strategy is used?	How does/did the child get down from the furniture?	Does/did the child interact similarly with other furniture items?	Do you have anything else that you would like to mention?	Are there any issues that we have not raised?
CP05	31	Use chairs	Call for help, tried to climb down herself	(no response)	(no response)	(no response)
CP06	65	Pulls a chair, opens cupboard, uses sink	(no response)	(no response)	(no response)	(no response)
CP07	50	N/A	Jump, climbs down to chair from kitchen table; flops onto seated part of couch	No	No	No
C001	60	N/A	N/A	Yes - TV console, table; jumping/pull up	Sitting, tipping chair, almost fell	(no response)
C002	54	N/A	jumps off couch	No	just couches	(no response)
C003	29	N/A	N/A	Yes - nightstands, bathtub	(no response)	(no response)
C004	51	sat in lower drawer, grabbed upper ones	feet out, step down	Yes - coffee table, side table	climbing couch, falling and jumping	(no response)
C005	47	N/A	N/A	N/A	No	(no response)
C006	21	opens more than one	crawls (tummy); daredevil will throw himself down	No	(no response)	(no response)
C007	58	N/A	N/A	No	bolted TV to wall; no more than 3-high dresser	6-yr-old nephew pulled dresser over on himself - old, heavy furniture. We are very safety conscious
C008	35	N/A	N/A	No	playgrounds, couches	(no response)
C009	42	N/A	climbs off bed, chair	No	dining table - climbs from chair; bookshelf - no climbing	sometimes helps with dishes - gets stool so he can reach
C010	36	N/A	slides off, belly to furniture front	N/A	None - not a huge climber	(no response)
C011	46	N/A	N/A	No	will jump off furniture onto cushions on floor	(no response)

C012	30	N/A	N/A	Yes - barstools, climb over back of couch/chairs	climb/jump on parents' bed	(no response)
C013	23	N/A	(no response)	book shelf - hasn't tried climbing, tries reaching stuff up high - "mama help, need help"	gymnastics - triangle foam, toddler slide	(no response)
C014	32	N/A	N/A	Yes	No	(no response)
C015	65	N/A	N/A	No	cereal on top of fridge - step stool, onto counter; also things from upper cabinets	(no response)
C016	27	N/A	N/A	Just the couch; high chair - tries to climb in	she doesn't like doing dangerous things	(no response)
C017	41	N/A	N/A	Yes - book case - cool stuff on top	(no response)	He does love climbing, husband has bolted everything to the wall
C018	28	N/A	N/A	Yes - pull out drawers in kitchen	none - not quite as adventurous as Matthew	(no response)
C019	42	lowest drawer - stepped in, tried to stand	ask for help, crawl out	Yes - used to climb on book shelf - hold & lean back	Used to crawl out of crib. Will find chair or step stool if she's really determined.	Rope climb at playground
C020	48	from bed to dresser	climbs down handles; climbs onto bed from top of dresser	No	No	(no response)
C021	54	from bed to dresser or climbs handles	jumps; climbs down handles; jumps onto bed	Yes	No	(no response)
C022	22	N/A	N/A	Yes - reaches to get things	No	(no response)
C023	29	lift leg up into other	catch her, brother lets know	(no response)	stacks stuff if she can't reach	(no response)
C024	20	(no response)	couch - flip on belly & slide down; whines to get off of bench	(blank)	(no response)	(no response)
C025	28	N/A	N/A	Yes	No	(no response)
C026	56	N/A	N/A	No	Good climber, rock wall, hoops at gymnastics for monkey bars; limited fear, advanced climber	(no response)
C027	35	N/A	N/A	No	No	Window sill
C028	57	pulls drawers out, uses cubbies as step; knobs	jumps	No	been climbing since he could	(no response)
C029	38	N/A	N/A	Yes - climbs in & out of bathtub	doesn't climb very much	(no response)

C030	33	N/A	N/A	No	climbs on arm of couch to reach top of Ikea cube	(no response)
C031	29	N/A	N/A	No	No	(no response)
C032	21	N/A	N/A	No	tries to climb in washing machine, car	(no response)
C033	42	step in, doesn't go past bottom	step/jump	Yes - end table drawer	No	(no response)
C034	57	don't know	fell	No	No	(no response)
C035	38	N/A	N/A	Yes - nightstands, pushes up	(no response)	(no response)
C036	52	(no response)	(no response)	No	outside - playground equipment	(no response)
C037	23	(no response)	(no response)	Yes - gets down by climbing	more interested in climbing	(no response)

Table 4
Child Participant Answers

Subject Number	Age at Testing (in months)	Do you like climbing?	What types of things do you climb?	How do you climb?	What do you do with the [furniture item mentioned by parent]?	If there is something in or on the item that is hard to reach, how would you try to get it?
CP05	31	(no response)	(no response)	(no response)	(no response)	(no response)
CP06	65	Yes	Monkey bars, play structure, kitchen counter, bunk bed ladder	Jump up on the counter	Couch, back left off the	(no response)
CP07	50	Yes	Stairs/steps; bridge	Hands & feet	(no response)	(no response)
C001	60	Yes	Jungle gym, rock wall, couch, monkey bars	hands/feet, jump off	climb behind couch, jump down (recliner pockets)	tippy toes, step stool
C002	54	Yes	bed, couch, monkey bars	climb straight, climb up the side	pick clothes; open drawers one at a time	ask mama or dada
C003	29	Yes	slide stairs, chairs	(no response)	(no response)	(no response)
C004	51	Yes	treehouses, ladders, monkey bars, slide	hands and feet	(no response)	hands, climb ladder
C005	47	Yes	handles, trampolines, stairs	frontways	desk: play on it - stand with a stool to climb on	use a stool; jump up
C006	21	(no response)	(no response)	(no response)	(no response)	(no response)
C007	58	Yes	everything! Big blocks, couch. Gymnastics - I love the bars to swing on - no flips	I personally just climb like a human does	N/A	stool, pillow on stool to make it taller
C008	35	Yes	playground	N/A	N/A	get dad to help me
C009	42	Yes	chairs; monkey bars	hands & knees - pulls himself up	bed - jump, play; bunk bed - climb up stairs/ladder; couch - sit on back, jump, play	asks parents for help
C010	36	Yes	Boxes, roofs	like a monkey, step stool, hands and feet	climb on kitchen counter to reach stuff	(no comment)
C011	46	Yes	ladder	(no response)	(no response)	(no response)
C012	30	Yes	(no response)	(no response)	(no response)	(no response)
C013	23	(no response)	(no response)	(no response)	(no response)	(no response)
C014	32	(no response)	(no response)	(no response)	(no response)	(no response)
C015	65	Yes	gym - room with play structure, 3 floors, stairs	couch - hands and feet	get clothes out of dresser	step stool
C016	27	child wouldn't respond	(no response)	(no response)	(no response)	(no response)
C017	41	Yes	climbing walls, ropes	Hands & feet	get clothes out of dresser	climb up with branches
C018	28	Yes	couches	climb it	open drawers, close drawers, put clothes in and out of	ask mama

					drawers; climb the slide with feet	
C019	42	Yes	Mom & dad's bed; climb stairs at playground; ladders - little ones, handles; slide on slides	stepping; hands on sheets of bed, step	climbing up	handles; hands; tiptoes; mommy could help
C020	48	Yes	ladders, slides	feet on ladder; hands & feet on stairs	get clothes out of dresser	use stool
C021	54	Yes	bars; ladder - bunk bed; paddles on playground	hands & feet (ladder); bars - only two hands, stepping	Kitchen counter - hands and feet	Kitchen counter - hands on top of counter, use feet to push body up and get it
C022	22	Yes	(no response)	(no response)	(no response)	(no response)
C023	29	(no response)	(no response)	(no response)	(no response)	(no response)
C024	20	(no response)	(no response)	(no response)	(no response)	(no response)
C025	28	Yes	I don't know	Hands	I don't know	(no response)
C026	56	Yes	window sills (do splits in the window); tables when I can't reach stuff out of the cupboards, climb on counters	table, chairs	(no response)	find little chair to get candy; with dinner chair
C027	35	Yes	Monkey bars	(no response)	(no response)	with a chair
C028	57	Yes - really high	playground - everything	(no response)	(no response)	(no response)
C029	38	No	(no response)	(no response)	(no response)	(no response)
C030	33	Yes	(showed climbing on chair)	hands & knees	don't jump on the couch!	jump! Mom says she'll use stool - bring something to counter to reach
C031	29	Yes	table; chairs; ladder at playground	hands & feet/knees	coffee table - elbows/knees - shimmy	don't know
C032	21	(no response)	(no response)	(no response)	(no response)	(no response)
C033	42	Yes	monkey bars like Arthur	hands and hands	rocks at home - TV remote - the regular one to turn the show off	(no response)
C034	57	Yes	couch; ladder (bed); kitchen (counters); playground - twirly, rock wall	hands & feet	climb on chair - can reach all the windows	tippy toes; jump up hIgh & grab it; stool/ladder
C035	38	Yes	couch, counters	(no response)	(no response)	climb hands & feet
C036	52	Yes	couch, slide, tire, bed, treehouse	hands and feet	(no response)	mom
C037	23	Yes	slide, chairs, brother	by myself	(no response)	reach, mom, brother

APPENDIX H

As part of the study, CSPC staff provided UMRTI researchers with list of publicly available videos of children interacting with CSUs and other similar furniture items in the home. Staff found these videos by using combinations of keywords to search YouTube. Keywords included, but were not limited to: child, toddler, baby, dresser, chest, drawer, cabinet, armoire, furniture, climb, open, jump, empty, fall, tip, and tip-over. Combinations of keywords included, but were not limited to: “climb dresser,” “child climb,” “child drawer,” “open drawer,” and “child dresser.” Staff also viewed related videos that were recommended by YouTube, allowing staff to follow a chain of videos of interest that weren’t necessarily included in the original search results. Search results included videos uploaded by consumers as well as segments of news reports and other media. Still images from some of these videos are shown in this report.

UMTRI researchers supplemented these videos with additional videos that they located.