United States
Consumer Product Safety Commission

October 10, 2024

CPSC Staff Statement on University of Michigan Transportation Research Institute (UMTRI) "Child Strength Measures: Children 24 through 71 Months Old"[1]

The report titled, "Child Strength Measures: Children 24 through 71 Months Old," presents the results of an in-lab human subjects study on the functional strength of 400 children ages 2 years old through 5 years old. Research was conducted in a purpose-built laboratory outfitted with force measurement equipment using fixtures and procedures developed for this study. Researchers designed 36 exertion tasks including pushing and pulling with one and two hands at four vertical positions while standing, pushing and pulling with one and two hands while seated, pushing with both feet while seated, pushing and twisting with the fingers and thumb, pulling the hands apart, and pushing with the shoulder. The participants' body dimensions were characterized through manual anthropometric measurements and 3D scanning. Researchers reported strength and anthropometric summary statistics for boys, girls, and the combined population for five age groups: 24 – 29 months, 30 – 35 months, 36 – 47 months, 48 – 59 months, and 60 – 71 months.

Work was completed under CPSC contract 61320618D0004. The purpose of this contract was to expand and update the available strength data for children five years old and younger. Consumer Product Safety Commission (CPSC) staff use data on human strength and capabilities to develop product safety standards and inform other CPSC staff activities. Strength capabilities of children are essential information to incorporate into the design of products that are intended for children to reduce or eliminate the risk such products might pose to a child (e.g., breaking, collapsing, or liberating a small part). In addition, products not intended for children but that can be hazardous to children can be made safer by incorporating performance requirements that consider children's' ability to interact with product components.

The study protocol was approved by a University of Michigan Institutional Review Board for research with human subjects (HUM00158177), and the data-collection protocol was reviewed and approved by the U.S. Office of Management and Budget under the provisions of the Paperwork Reduction Act (OMB Control No 3041-0187).

There are two companion research studies that are being released with this report: "Child Strength Measures: Children 6 through 23 Months Old," and "Bite Force for Children 3 through 71 Months Old."

[1] This statement was prepared by the CPSC staff, and the attached report was produced by the University of Michigan Transportation Research Institute for CPSC staff. The statement and report have not been reviewed or approved by, and may not represent the views of, the Commission.

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Child Strength Measures:

Children 24 through 71 Months Old

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CONTRACTOR INFORMATION

This work was conducted by the University of Michigan Transportation Research Institute for the U.S. Consumer Product Safety Commission under contract number 61320618D0004. The work described in this report was conducted under Task Order 1: Strength Data Update: Strength Measures for Children 2 through 5 Years Old.

The authors thank the child participants and their caregivers for their patient and valuable interactions. The methods and data presented in this report resulted from the contributions of a large team of talented and dedicated individuals. We are particularly grateful to the data collection team, who patiently refined the methods for working with these young children to generate useful data. The data collection team included: Sarah Rose Beechboard, Miaya Boykin, Laura De Marzi, Thane Deming, Joe McMillan, Alayna Roscoe, Kristina Rowden, and Shinhae (Grace) Yeo. Jamie Moore led participant recruitment, which was critical to ensuring the success of the project.

The laboratory facility and instrumentation were developed specifically for this study and represent a large amount of innovation and creativity. Contributors to the facility and instrumentation included Brian Eby and Jen Bishop. Kyle Boyle contributed to the design of the force-measurement fixtures and Alan Liu produced the engineering drawings of the interfaces.

EXECUTIVE SUMMARY

Data on children's strength is critically important for the design of safe products. However, few studies have gathered data from children younger than 6 years of age, and most samples have been small. To address this need, 400 children ages 24 through 71 months were recruited to participate in a laboratory study focused on functional strength. A dedicated laboratory was equipped with specially constructed fixtures and instrumentation, including a novel visual force-feedback system. A set of 36 exertion tasks were designed that included standing pushing and pulling with one and two hands at four vertical positions, seated pushes and pulls with one and two hands, seated pushing with both feet, pushing and twisting with the fingers and thumb, pulling the hands apart, and pushing with the shoulder. Due to the large number of conditions, each participant completed a subset of tasks, but data from at least 23 participants were gathered for each exertion. The participants' body dimensions were characterized through manual anthropometric measurements and 3D scanning. The data were verified using a manual process that involved visual inspection of synchronized force and video data to ensure that the task was performed as instructed. The peak value of a one-second moving average over the course of each valid trial was analyzed. Three trials were attempted in each condition and the maximum value for each subject in each condition was used in the analysis. Summary statistics were computed for boys, girls, and the combined population for each age group.

BACKGROUND AND OBJECTIVES

Strength data for children are needed to improve the safety of products for children through testing and support for standards development. For example, gates used to guard hazards in the home are tested to ensure that they cannot be opened or dislodged by the forces that children are capable of exerting. Currently, minimal information on strength is available for children under age 6 years.

Brown et al. (1973, 1974) conducted a study of strength capabilities of children ages 2 through 6 years. The intent was to develop standards for toys and products. Two custom devices were developed: a push-pull and pull-apart tester to quantify hand and grip strength for a range of postures. The push-pull tester included several attachments: small diameter knob, narrow lever covered with a rubber sleeve, pull chain connected to a lever, twister (small diameter knob) mounted on top and front of testing device, and a hand dynamometer. The pull-apart tester included two cylindrical, T-shaped handles. No adaptations were made in the test rig to account for child anthropometry. For the push-pull measures, the tester was secured to a table, approximately 20 inches from the floor, and child participants were encouraged to use innovation, creativity, and volition to achieve maximum performance, approximating a more normal play condition. For the pull-apart measures, the child participant held the instrumented cylinder parallel and approximately perpendicular to the shoulders at chest height and pulled the handles apart, bilaterally and with the left or right hand extended forward. In addition to verbal encouragement, the testers provided feedback using a row of colored lights, with the number of illuminated lights proportional to force exerted. Sample size for this study was 50 children in each age group. The customized equipment was developed and calibrated for reading error not to exceed 9 N for any measure. With the exception of children aged 2 through 3 years old, boys were found to have greater average maximal strength than girls, though the difference in absolute magnitude was small. Strength was also observed to increase linearly with age.

Owings et al. (1975) conducted a study of the strength of U.S. children, ages 2 through 10 years, with the intention of informing product safety design. The study included 33 isometric exertion measures conducted on an instrumented reclining chair. Isolated joint strength was measured at wrist, elbow, shoulder, ankle, knee, hip, and trunk. Torque was quantified about the available degrees of freedom (e.g., shoulder flexion, extension, adduction, abduction, medial and lateral rotation). The customized chair included a series of cantilevered beams to form an adjustable exoskeleton that articulated in at least one plane and aligned to the center of rotation for each joint. Anthropometric measures were taken to scale the chair to fit each child. Friction contact surfaces and Velcro straps were used to standardized body posture without causing discomfort. To elicit maximal voluntary effort, caregivers and research staff provided verbal encouragement and visual feedback via a graphical display. Criterion for an acceptable measurement was defined as an exertion sustained for 4 to 6 seconds, that was reasonably repeatable in a test-retest, and representative of real-world observations in child strength. Force values were extracted using a moving average over one second during the three seconds of the exertion. Sample size for this study was 20 to 30 children per group. For most measurements, no significant differences were noted between boys and girls, but strength was found to increase with age. Population estimates of isolated joint strength data were input to a computerized biomechanical model.

Grip strength measurements and upper extremity joint strength of children ages 2 through 10 years were collected as part of a larger study (Owings et al. 1977). Isolated joint strength about the elbow joint was quantified through a range of angles from flexion through to full extension. These measures were conducted using the instrumented reclining chair and protocol described for the whole-body joint torques. Grip strength measures included two-point (*i.e.*, thumb and index finger), three-point (thumb, index, and middle), and five-point (all digits) pinch grips, a lateral pinch grip, and squeezing with different levels of hand closure. Grip strength measures were scaled to hand dimensions and performed at a range of one-centimeter increments between 2 and 9 cm. A customized grip transducer with varying handle sets was developed for this study. Force exertions were quantified as a two-dimensional vector, defining the direction, magnitude, location of the resultant force in terms of normal and shear components.

Norris and Wilson (1995) published a comprehensive compendium of child anthropometry and strength measures titled "CHILDATA" [sic] that draws on a wide range of sources. This design resource is distinguished from earlier work as it focused on functional measures rather than isolated joint strength as in the Owings et al. work. Data on body dimensions, strength, motor abilities, skills related to specific products, and psychological data were compiled from published sources for populations from the U.S., U.K., and the Netherlands. Exertions included push forward, push downwards, push sideways, pull, lift up against a range of handle configurations, in both vertical and horizontal orientations and in standing and seated postures. Hand grip strength measures included hitting force with a fist, wrist twist, opening strength, squeeze grip, and several pinch grips. Sample sizes were typically fewer than 20 per age group.

The U.K. Department of Trade & Industry, Government Consumer Safety Research (2000) conducted a strength study for design safety. Anthropometric and strength measurements were recorded for 150 participants ranging from 2 to 90 years of age (n=17 for children ages 2-5). Hand strength measures included: finger push, pinch-pull, hand grip, wrist-twisting, opening strength, push and pull strength. Additional measures characterizing whole-body strength were also captured (DTI, 2002). Measures included: maximal push and pull strength, push with thumb or two or more fingers, push with shoulder, maximal pull with different grips, wrist twisting and push-and-turn strength, pull on a can ring-pull, and press and lift with foot. Force targets were presented in a range of size configurations, orientations and locations defined by participant anthropometry. Participants used their dominant hand and self-selected posture during exertions. Visual feedback was provided throughout the protocol. Strength was observed to increase with age and for most measurements no significant gender differences were found.

A primary conclusion from synthesizing and attempting to apply the prior literature in this area is that a rich dataset of functional strength measures is needed for future analyses. The objective of the current study was to develop instrumentation, laboratory fixtures, and protocols to measure functional strength for children 2 through 5 years old and to gather data from a large sample of children.

METHODS

Overview

A dedicated laboratory, fixtures, and procedures were developed for this study. The design of the study was informed by pediatricians and other child development experts, as well as engineers with extensive experience with adult anthropometry and strength testing. A visual feedback system was developed and refined through pilot testing, and the data collection team participated in ongoing training to ensure consistent procedures. Forces were exerted on idealized interfaces intended to maximize force production. Summary statistics were computed for the maximum forces exerted by each child in each condition.

Institutional Review Board Approval

The protocol was approved as part of the protocol for the larger strength study by a University of Michigan Institutional Review Board for research with human subjects (HUM00158177), and the data-collection protocol was reviewed and approved by the U.S. Office of Management and Budget under the provisions of the Paperwork Reduction Act (OMB Control No 3041-0187).

Laboratory Layout

The design of the laboratory layout for this study placed importance on the engagement and interaction between the child participant and investigator. Upon arrival to the University of Michigan Transportation Research Institute (UMTRI), a child participant and caregiver were greeted by an investigator at their personal vehicle, who escorted them to the reception area and laboratory facilities. Child-size footprints on the floor highlighted the path to the laboratory, and signage was placed in the hallways leading to the laboratory spaces to help the children feel comfortable. Informed consent was obtained in a child-friendly reception room. The intent of the reception room was to provide an environment that enabled an investigator to engage the child in age-appropriate, play-based interaction and to briefly assess the child's temperament, physical, and verbal development. Figure 1 illustrates the initial engagement at UMTRI and the child-friendly reception room.

A purpose-built laboratory outfitted with force measurement equipment, child-friendly furniture, and surfaces was developed for this study. The laboratory was designed to help the child feel safe but alert. The color scheme, testing structure, and handle interfaces were intentionally muted to emphasize the engagement between the child and investigator. The presentation of the measurement apparatus was minimized to not cause distraction or look scary. The most visually interesting object in the testing environment was the force feedback display. The physical laboratory space also ensured privacy and sufficient space. Transparent partitions enabled the lab to separate a dedicated rest space from the testing structure for the child participant, caregiver, and siblings. This provided a safe place to take breaks and rest when the testing fixtures were being re-configured, and for caregivers and siblings to watch and support the child participant during a testing session. Figure 2 documents views of the child-friendly reception room and laboratory layout, showing the color scheme, partitioning, and dedicated rest space.

Figure 1. Welcome to UMTRI and reception room.

Figure 2. Photos of the laboratory designed for child strength measurement.

Laboratory Fixtures

The laboratory fixtures were designed to enable children to perform functional exertions with application relevance. Importantly, the primary structure was reconfigurable to enable participants to exert forces in application-relevant postures. This means that the children were allowed to select their postures within the range permitted by the task definition. The laboratory fixtures were highly adjustable to enable the task conditions to be scaled to a child participant's anthropometry. Similar to prior studies in the literature, we divided tasks into standing and seated and developed tasks that involve exertions with both the hands and feet.

The standing structure enabled the vertical and fore-aft location of the handle interfaces to be varied over a wide range (Figure 3). Handle locations were adjustable to the child's body dimensions by means of sliding, lockable components, and counterweighted lifting mechanisms. Standing exertions involved a child participant exerting force with one or two hands on different handle interfaces that were attached to six-axis load cells mounted on the horizontal sections. The fore-aft position of a horizontal section was set to locate the center of the interface over a force platform in the floor that captured ground reaction forces for each exertion.

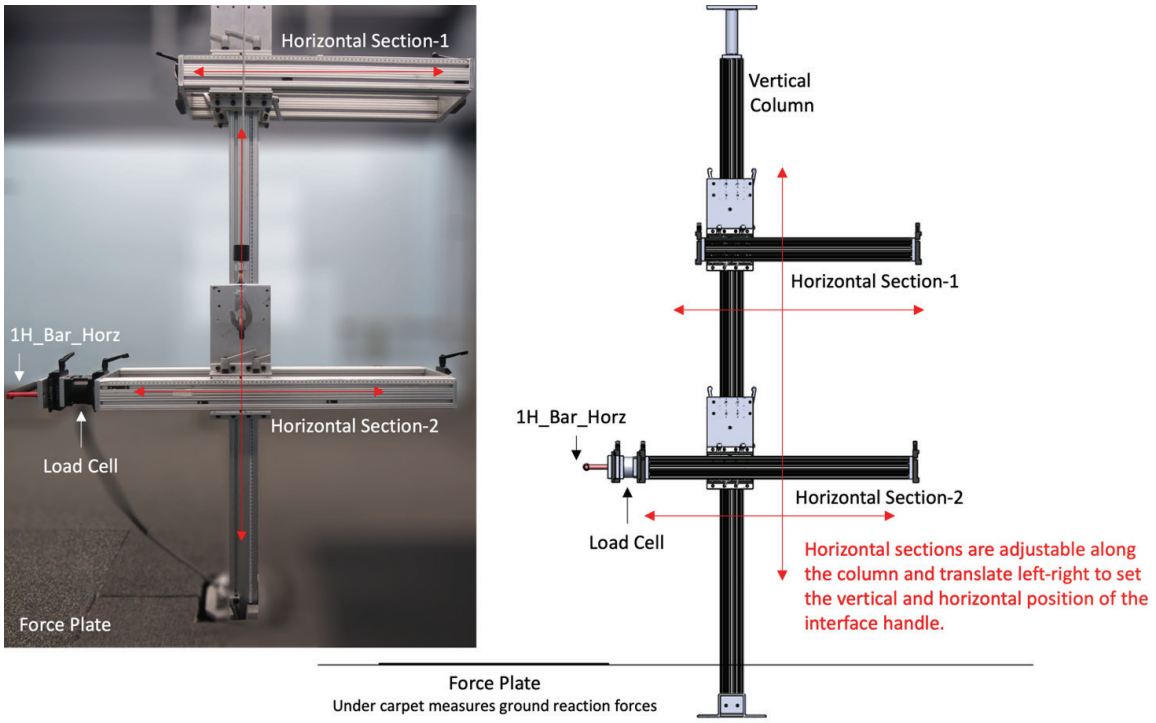

Figure 3. Primary structure components for the one-hand (1H) and two-hand (2H) standing exertions.

A chair was specially constructed for the seated conditions (Figure 4). Both the vertical height and pan length of the seat were adjustable and scaled to a child participant's anthropometry. The seatback was set to 10-deg inclination angle from vertical. A lap belt made from webbing material was used to safely position the child within the seat. Seated tasks were divided into one-hand (1H) and two-hand (2H) configurations. Seated 2H exertions included pushes and pulls with the hands. Forces were also measured for seated pushes with both feet in the same configuration used for 2H exertions with the seat oriented to face the vertical column (Figure 4). Both the 2H handle interface and foot plate were attached to six-axis load cells mounted on the horizontal sections. The vertical and horizontal position of the horizontal sections were adjustable to a child participant's body dimensions. For seated 1H exertions, the seat was rotated 90 degrees, so the child faced laterally relative to the horizontal sections of the structure (Figure 5). In the lateral-facing configuration, the 1H interface was attached to a load cell mounted on the horizontal section. The vertical and horizontal location of the 1H interface was scaled to the child's body dimensions.

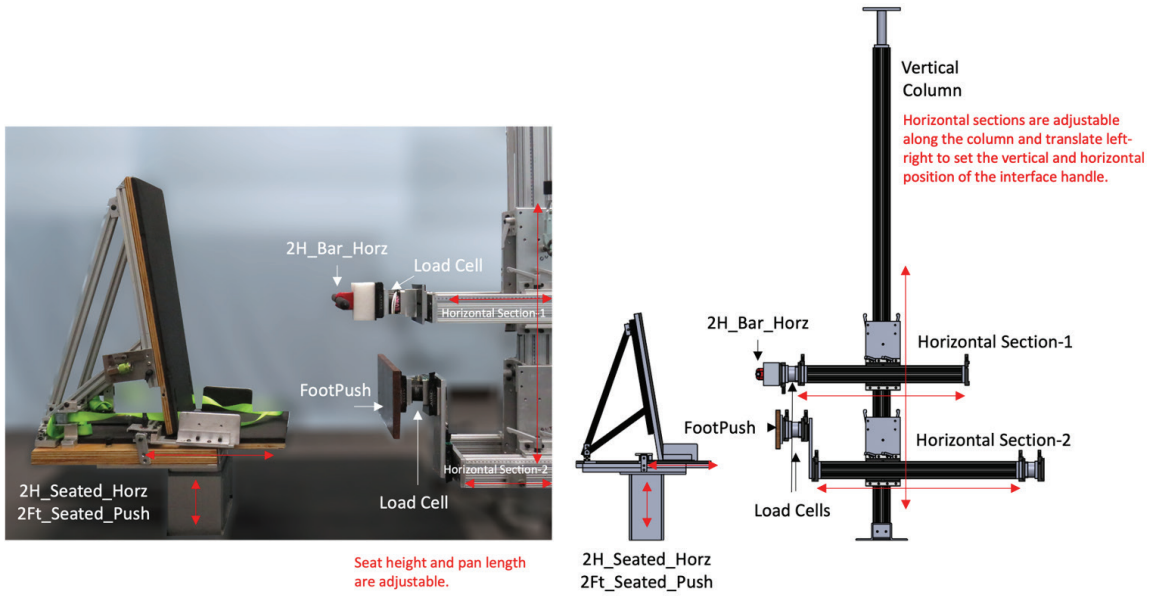

Figure 4. Two-hand (2H) seated configuration.

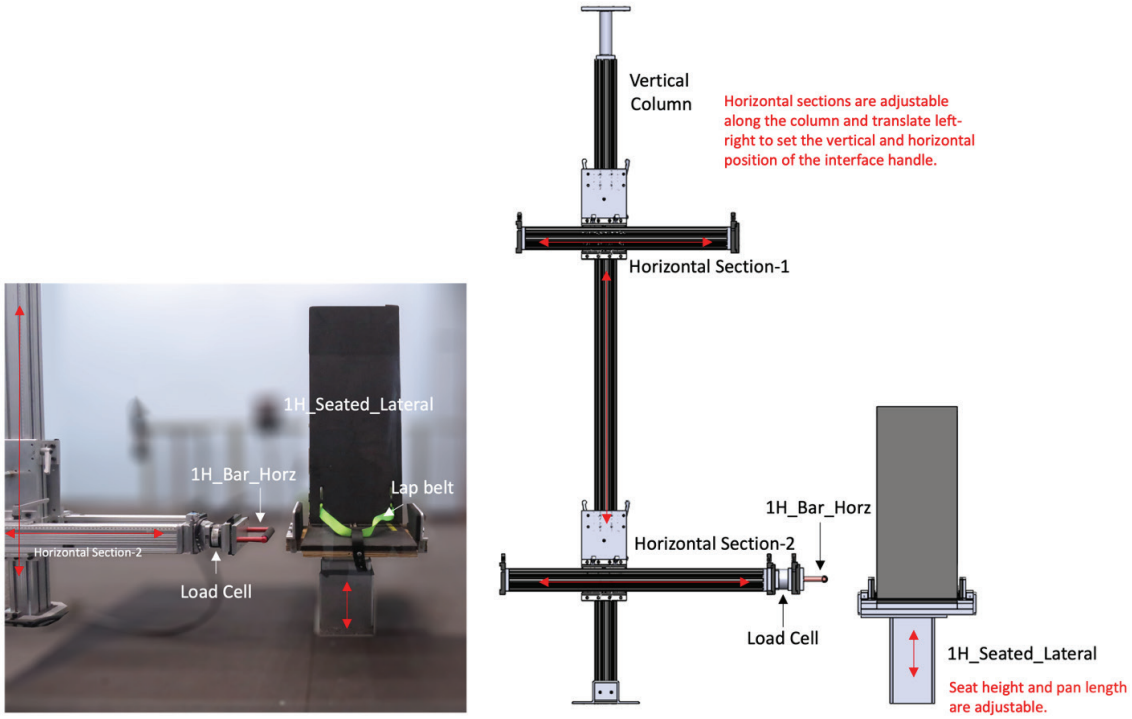

Figure 5. One-hand (1H) seated configuration.

The laboratory included features to improve the safety of the participants and investigators. Safety protocols required child participants be behind the room divider in the “rest space” prior to investigators adjusting or setting the horizontal sections on the testing structure. The adjustable interface features were safeguarded by locking mechanisms, including four locks to secure the vertical position and four locks to secure the horizontal position of each horizontal section with respect to the vertical column. Padding was also applied to the load cells and sharp edges on key components of the testing structure. Figure 6 illustrates the padding and the lift assistance and locking mechanisms.

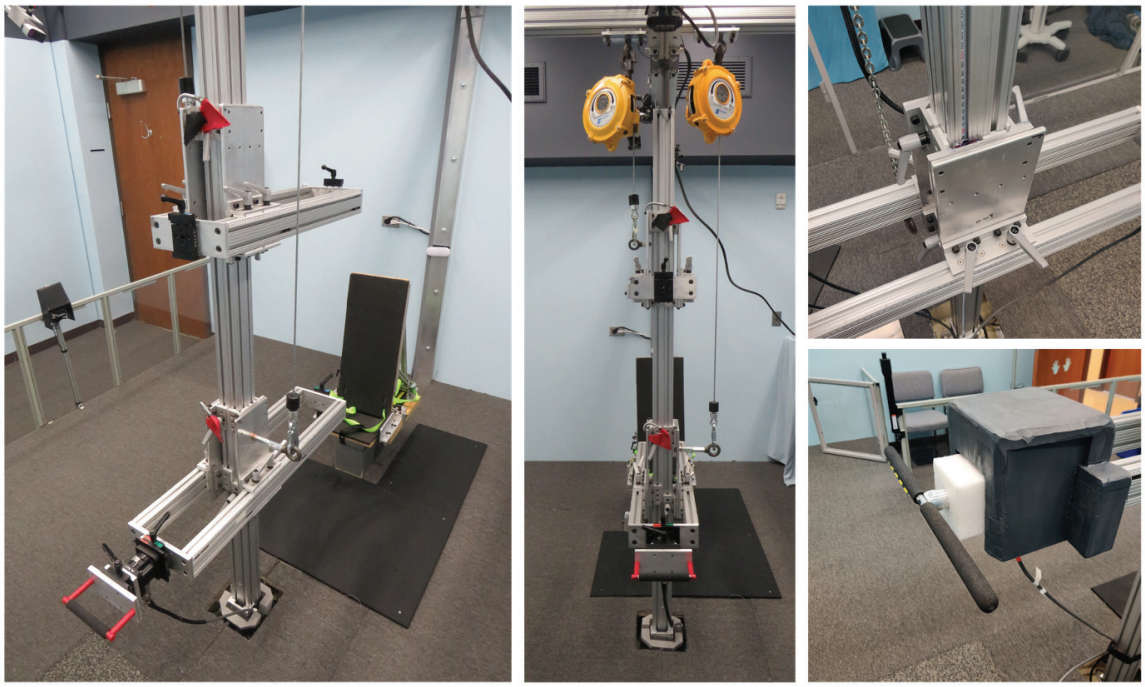

Figure 6. Safety features of the testing structure. The load cell behind the 1H interface is shown uncovered at left and covered with padding on the right lower image. The center image shows the lift-assist devices (yellow) that helped to manage the weight of the horizontal components of the structure during adjustments.

Instrumentation

Data were recorded using load cells, a force platform, and camera systems. Force data were gathered with both six-axis and uniaxial load cells, with the specific number and combination varying depending on the task being performed (Table 1). The signals from the load cells were recorded and conditioned using a National Instruments cDAQ-9179 chassis and NI9237 bridge input modules. Each data channel was sampled at a frequency of 2000 Hz and filtered digitally using an 8-pole zero-phase low pass Butterworth filter with a passband frequency of 0-1000 Hz. The load cells were factory calibrated, and crosstalk matrices were used with the six-axis load cells to eliminate errors introduced by off-axis loading. Each load cell signal was verified by suspending an 89 N static mass and ensuring that the recorded force was within 2% of the expected load (Figure 7). Appendix A documents the load cell configurations for the interface handles and individual strength measures.

Table 1
Load Cell Manufacturer, Model, and Capacity

Manufacturer	Model	Capacity*					
		Fx (N)	Fy (N)	Fz (N)	Mx (Nm)	My (Nm)	Mz (Nm)
AMTI	MC3A-6-1000	2200	2200	4400	110	110	56
AMTI	OR6-7-1000	225	225	4450	1130	1130	565
Denton	3300	12000	12000	14000	450	450	300
Interface	WMC-250	1112					
Interface	WMC-100	445					

* Rated maximum full-scale force on three orthogonal axes (Fx, Fy, and Fz) along with the maximum rated moment around those axes (Mx, My, Mz). The data in this report were gathered on the Fx axis (horizontal pushes and pulls), and the Fz axis (push/pull up/down). Twist exertions were recorded on the Mx axis.

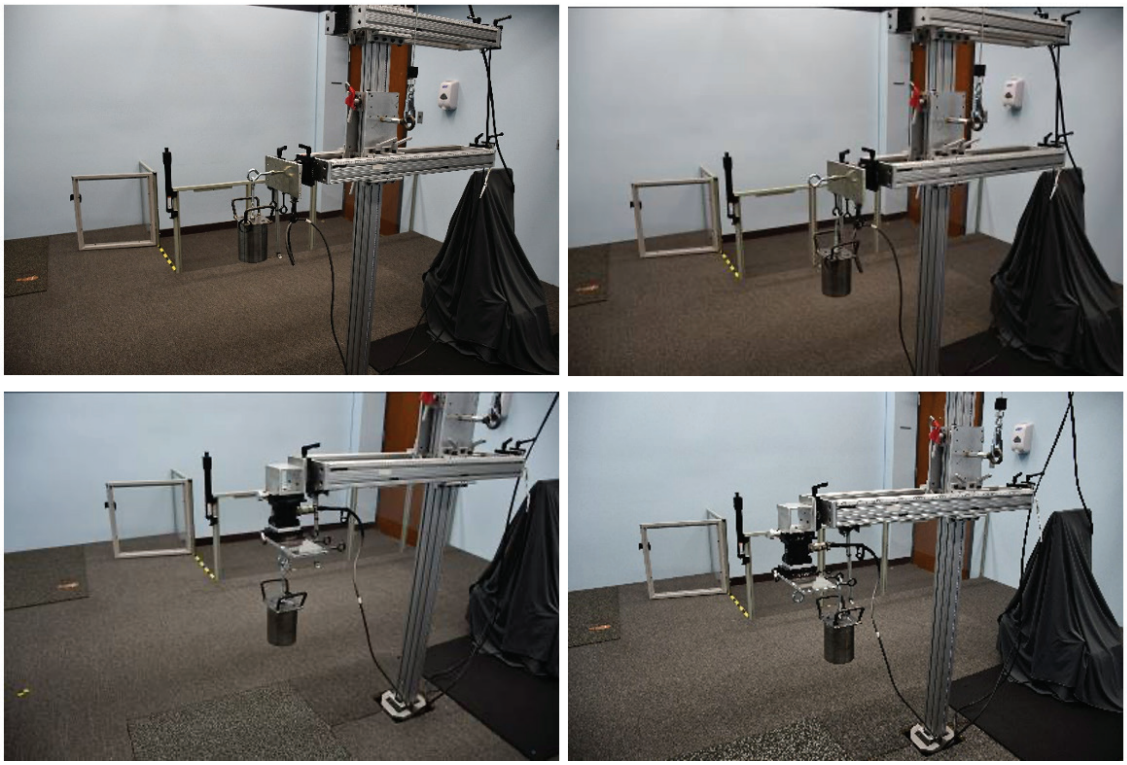

Figure 7. Load cell verification using 89 N static weight. The load cell orientation and weight position were adjusted as needed to verify each force and moment axis.

Interfaces

Forces are exerted on the environment through interfaces that affect the outcomes. For example, a sharp edge on an interface could limit the force that a child is willing to exert. When considering the variety of potential interfaces, postures, and force directions, the number of tasks of interest was very high. Our selection of interfaces was governed by the following design considerations:

1. *Application relevance* – The choice of interface limits the applicability of the data. Laboratory tasks are idealized versions of real-world tasks but, to be useful, must map well to tasks of interest for design.
2. *Size* – The diameters of interfaces such as cylindrical bars used for push/pull tasks affect outcomes, particularly for pulls. Ideally these would be varied, to quantify the effects, but this was not practical in the current study given the limited amount of time available with each participant.
3. *Shape* – Similarly, the shape of the interface can have large effects, particularly for hand-intensive tasks, such as twisting smooth vs. knurled knobs.
4. *Friction* – The friction at the task interface is often a limiting factor, for example, when pulling on a cylindrical handle. The choice of interface features affecting friction poses a conflict between the desire to maximize force generation and reproducibility. Flat, smooth metal surfaces provide the best reproducibility, but surfaces coated with high-friction materials will result in higher force values and may be more application relevant. In the current study, both types were used.
5. *Reproducibility* – The challenge of creating reproducible methods means that all interfaces must be described well enough to be recreated in all details that affect results. For this reason, custom interfaces are generally preferred over commercial products, for example. The documentation for the current study includes relevant dimensions and materials along with fully dimensioned engineering design drawings (Appendix B).

Table 2 lists the interfaces used in this study. Engineering drawings and detailed specifications for each interface can be found in Appendix B.

Table 2
Force Application Interfaces

Interface	Description	Image
1H_Bar_Horz	Cylindrical horizontal bar, 139 mm long and 21 mm in diameter, attached to a six-axis load cell. The bar was coated in vinyl foam that provided a high-friction grip.	
2H_Bar_Horz	Cylindrical horizontal T-bar, 475 mm long and 21 mm in diameter, attached to a six-axis load cell. The handle was coated in vinyl foam that provided a high-friction grip.	
Dynamometer_24	Custom hand grip dynamometer with the aperture adjusted to 24 mm. A uniaxial load cell was integrated within the fixture. The handle was fabricated with 6061 aluminum alloy. The dynamometer was mounted on a low-friction slide that supported the instrument vertically but did not allow application of horizontal force.	
FingerSurface	Finger surface interface (50 mm x 50 mm), attached to a six-axis load cell. Point of force application was visually indicated to child participant at the center of the finger surface (centered at 25 mm from edge). The surface was fabricated with 6061 aluminum alloy.	
PullApart_HandCouple	Asymmetric steel hand hold grips 10 mm in diameter with 54 mm and 57 mm lengths for hand coupling. A uniaxial load cell was integrated in the ball joint between the two hand grips.	
TurnKnob_40	Fluted hexagon radiused knob with 5 mm radii and 40 mm outer diameter, attached to a six-axis load cell. The turn knob was fabricated with 6061 aluminum alloy and accommodated 17 degrees of spring-loaded, clockwise rotation.	
PinchPull_19	Custom pinch pull fixture with tab interface aperture adjusted to 19 mm. A uniaxial load was integrated within the fixture to measure pinch force and the fixture was attached to a six-axis load cell to measure the pull force. The handle was fabricated with 6061 aluminum alloy.	
SquarePad	Square planar surface (102 mm x 102 mm), attached to a six-axis load cell. Plate is fabricated with 6061 aluminum alloy and covered with 12 mm of high-density foam.	
FootPush	A plywood surface (299 mm by 170 mm), attached to a six-axis load cell. Footprints on the planar surface provide a visual indicator for participants to place their feet.	

Strength Measures

In the laboratory, children performed a sequence of tasks to test maximal exertions with their hands and feet. Table 3A and 3B list the strength measures by category. The tables include a concise code that is used throughout the report to precisely reference each task. The same standing tasks (pushing forward, pulling backward, and pushing or pulling upward) were performed with both one and two hands and at four vertical positions, except that upward exertions were not performed at the overhead position. Hand strength tasks were performed standing.

Table 3A
Strength Measures by Category (One-Hand and Two-Hand Standing)

One-Hand Standing		Two-Hand Standing	
Description	**Code**	**Description**	**Code**
1-Hand, Thigh Height, Pull	1H_Thigh_Pull	2-Hand, Thigh Height, Pull	2H_Thigh_Pull
1-Hand, Thigh Height, Push	1H_Thigh_Push	2-Hand, Thigh Height, Push	2H_Thigh_Push
1-Hand, Thigh Height, Up	1H_Thigh_Up	2-Hand, Thigh Height, Up	2H_Thigh_Up
1-Hand, Elbow Height, Pull	1H_Elbow_Pull	2-Hand, Elbow Height, Pull	2H_Elbow_Pull
1-Hand, Elbow Height, Push	1H_Elbow_Push	2-Hand, Elbow Height, Push	2H_Elbow_Push
1-Hand, Elbow Height, Up	1H_Elbow_Up	2-Hand, Elbow Height, Up	2H_Elbow_Up
1-Hand, Shoulder Height, Pull	1H_Shoulder_Pull	2-Hand, Shoulder Height, Pull	2H_Shoulder_Pull
1-Hand, Shoulder Height, Push	1H_Shoulder_Push	2-Hand, Shoulder Height, Push	2H_Shoulder_Push
1-Hand, Shoulder Height, Up	1H_Shoulder_Up	2-Hand, Shoulder Height, Up	2H_Shoulder_Up
1-Hand, Overhead Height, Pull	1H_OverHead_Pull	2-Hand, Overhead Height, Pull	2H_OverHead_Pull
1-Hand, Overhead Height, Push	1H_OverHead_Push	2-Hand, Overhead Height, Push	2H_OverHead_Push

Table 4B
Strength Measures by Category (1H and 2H Seated, Hand Strength, Whole-Body Strength)

Seated (One-Hand and Two-Hand)		Hand Strength	
Description	**Code**	**Description**	**Code**
1-Hand, Seated, Pull	1H_Seated_Pull	Dynamometer, 24mm, Elbow, Grip	Dynamometer_24mm_Elbow_Grip
1-Hand, Seated, Push	1H_Seated_Push	Finger Surface, Index, Elbow, Push	FingerSurface_Index_Elbow_Push
1-Hand, Seated, Down	1H_Seated_Down	Finger Surface, Thumb, Elbow, Push	FingerSurface_Thumb_Elbow_Push
1-Hand, Seated, Up	1H_Seated_Up	Pull Apart, Hand Couple, 57mm	PullApart_HandCouple_Pull
2-Hand, Seated, Pull	2H_Seated_Pull	Turn Knob, 40mm, Elbow Height, Clockwise	TurnKnob_40mm_Elbow_CW
2-Hand, Seated, Push	2H_Seated_Push	Pinch Pull, 19mm, Elbow Height, Pull	PinchPull_19mm_Elbow_Pull
2-Foot, Seated, Push	2F_Seated_Push		
		Whole-Body Strength	
		Shoulder Push, Elbow Height, Push	ShoulderPush_Elbow_Push

Similar to our prior work with adults (Hoffman et al. 2011; Jones et al. 2013), the majority of the task conditions were scaled based on body size. This enables a focus on the strength of the child, rather than the population capability for the task. (The capability for any population of interest can be determined through subsequent analysis of the data.) For the 1H and 2H standing tasks, the vertical positions were set to 41%, 63% 77%, and 110% of measured stature (approximately mid-thigh, elbow, shoulder, overhead height). The horizontal position of the of the 1H and 2H interfaces were set to locate the center of interface 100 mm onto the force platform. Child participants were instructed to grip the 1H_Bar_Horz and 2H_Bar_Horz with one or both hands, and push forward, pull rearward, and push or pull upward as hard as they could (Figure 8). Figure 9 illustrates the 1H and 2H standing task conditions. Note that these photos were staged for purposes of illustration. During data collection, the photo backdrop was not present, the investigator was always close to the participant providing encouragement, and the caregiver was always present in the area immediately adjacent to the laboratory fixtures (see Figure 2).

Hand exertions were performed while standing, with the force interface presented at elbow height. Figure 10 shows illustrations of the push with finger, push with thumb, and pinch-pull conditions. A shoulder push was performed with the target pad located at elbow height, allowing the child to lean into the interface (Figure 11).

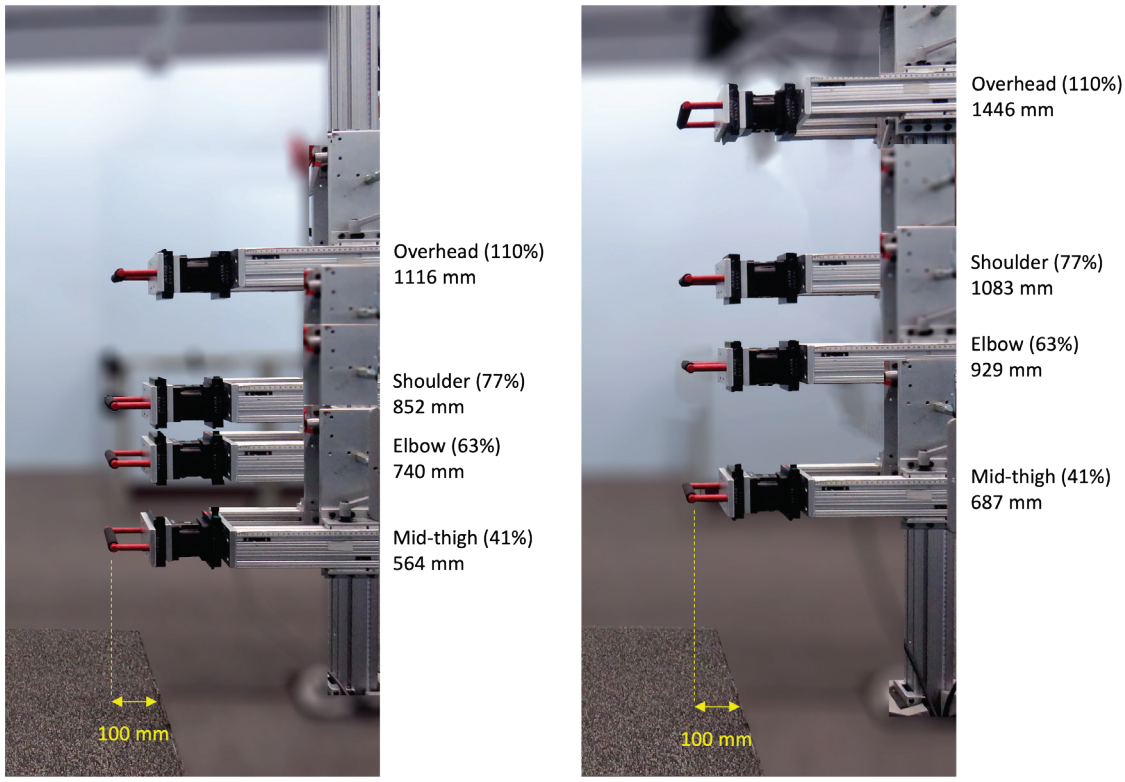

Figure 8. Illustration of 1H standing exertion configurations for the four vertical positions (mid-thigh, elbow, shoulder, overhead) scaled to a child with a stature of 800 mm (left) and 1100 mm (right).

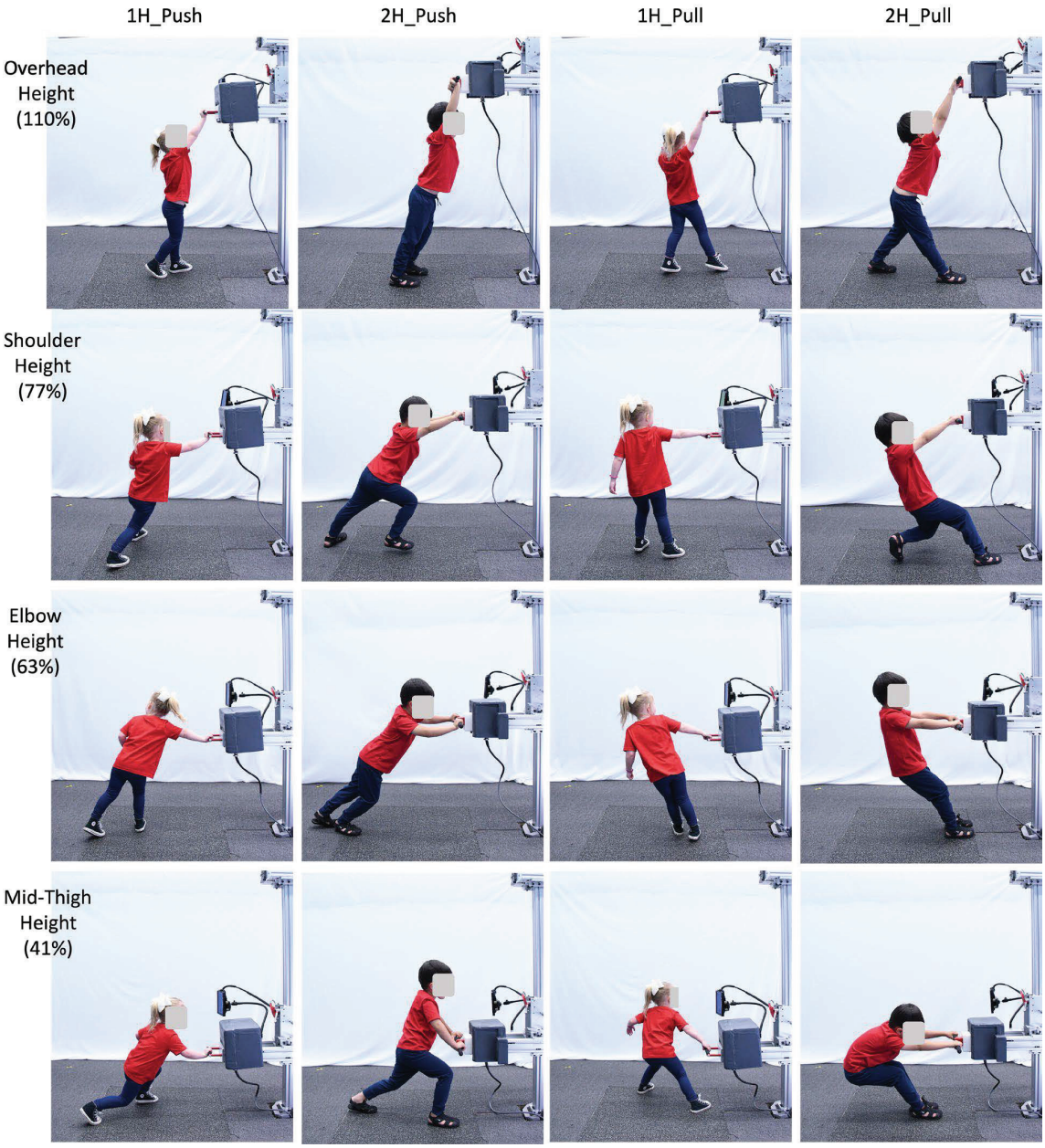

Figure 9. Illustration of one and two-hand standing push and pull exertions (1H_Overhead_Push, 1H_Shoulder_Push, 1H_Elbow_Push; 1H_Thigh_Push; 2H_Overhead_Push, 2H_Shoulder_Push, 2H_Elbow_Push; 2H_Thigh_Push; 1H_Overhead_Pull, 1H_Shoulder_Pull, 1H_Elbow_Pull; 1H_Thigh_Pull; 2H_Overhead_Pull, 2H_Shoulder_Pull, 2H_Elbow_Pull; 2H_Thigh_Pull). Note that the children depicted were not participating in the study; photos were staged for purposes of illustration.

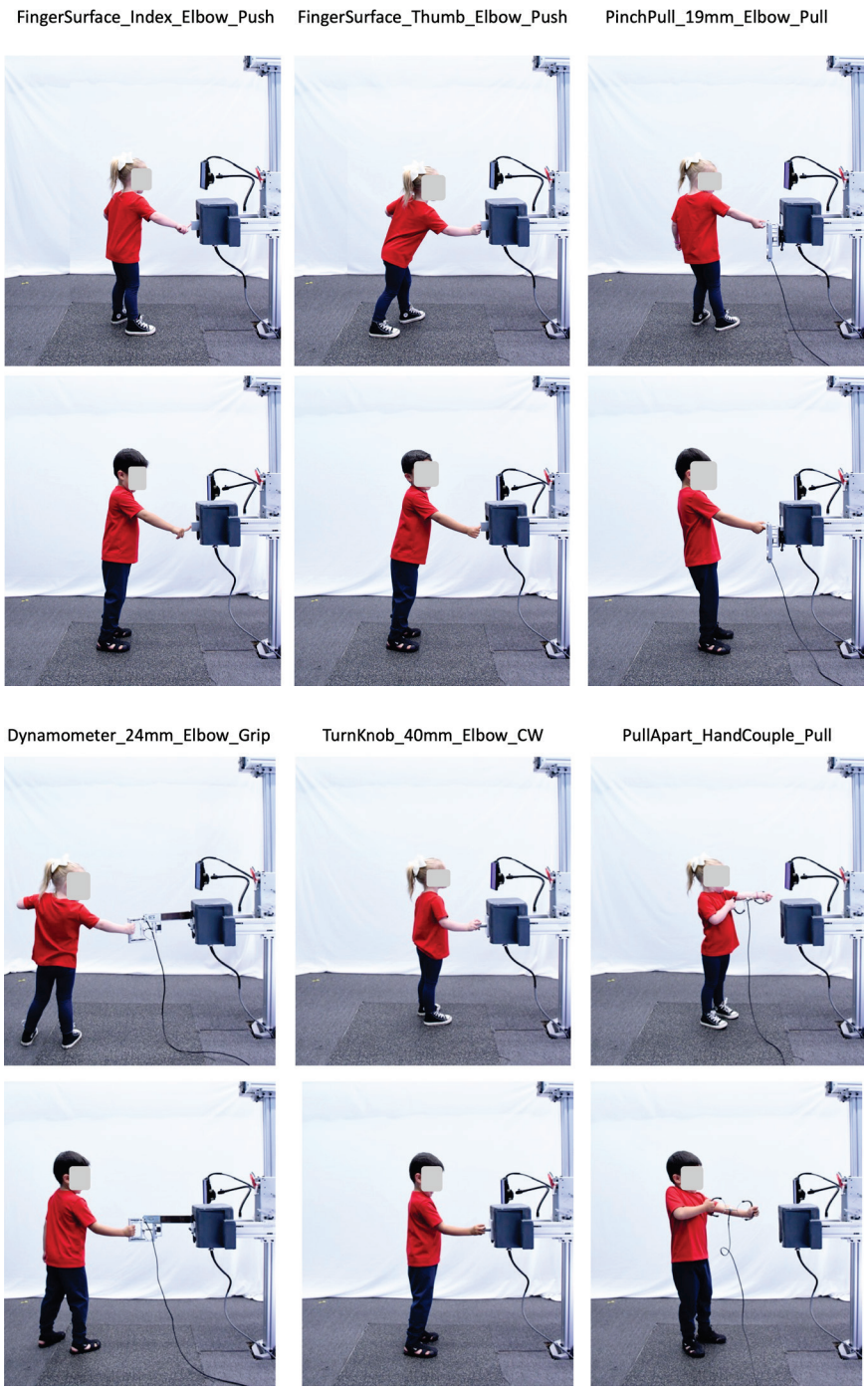

Figure 10. Representative hand strength exertions (FingerSurface_Index_Elbow_Push, FingerSurface_Thumb_Elbow_Push, PinchPull_19mm_Elbow_Pull, Dynamometer_24mm_Elbow_Grip, TurnKnob_40mm_Elbow_CW, PullApart_HandCouple_Pull). The upper and lower images in each column show different children doing the same exertion. Note that the children depicted were not participating in the study; photos were staged for purposes of illustration.

ShoulderPush_Elbow_Push

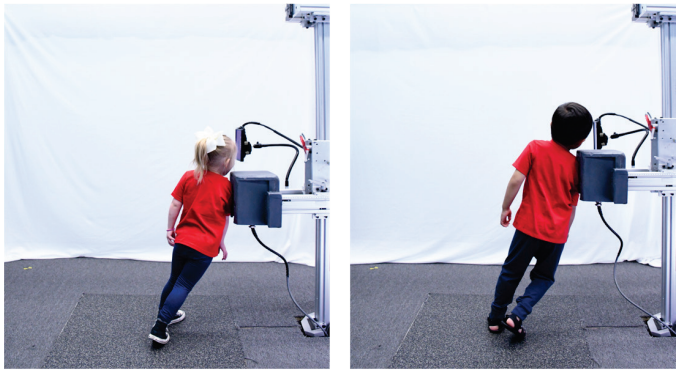

Figure 11. Representative whole-body strength exertions (ShoulderPush_Elbow_Push). The two images show different children doing the same exertion. Note that the children depicted were not participating in the study; photos were staged for purposes of illustration.

Seated tasks were scaled to achieve approximately equivalent knee and elbow angles across participants. The seat configuration was normalized by setting the seat height to knee height minus 25 mm (to predict popliteal height) and seat pan length to 90% of buttock-popliteal length (both dimensions were predicted from stature).

For 2H seated tasks, child participants sat facing the vertical column on the testing structure and the interface vertical position was set to 90% of seated acromion height, approximately chest height (Figure 12). The horizontal distance between the seat and the 2H_Bar_Horz interface was set to 100% and 70% of maximum forward reach prediction for 2H pull and push exertions respectively. The vertical position of the FootPush interface was set to align the lowest edge of the foot plate with the height of the seat. The horizontal distance between the rear edge of the seat surface (*i.e.*, the lowest point on the backrest) and the FootPush interface was set relative to 110% of the difference between stature and erect sitting height. All measures were predicted from stature. Figure 13 shows representative photos of the two-hand and two-foot seated tasks.

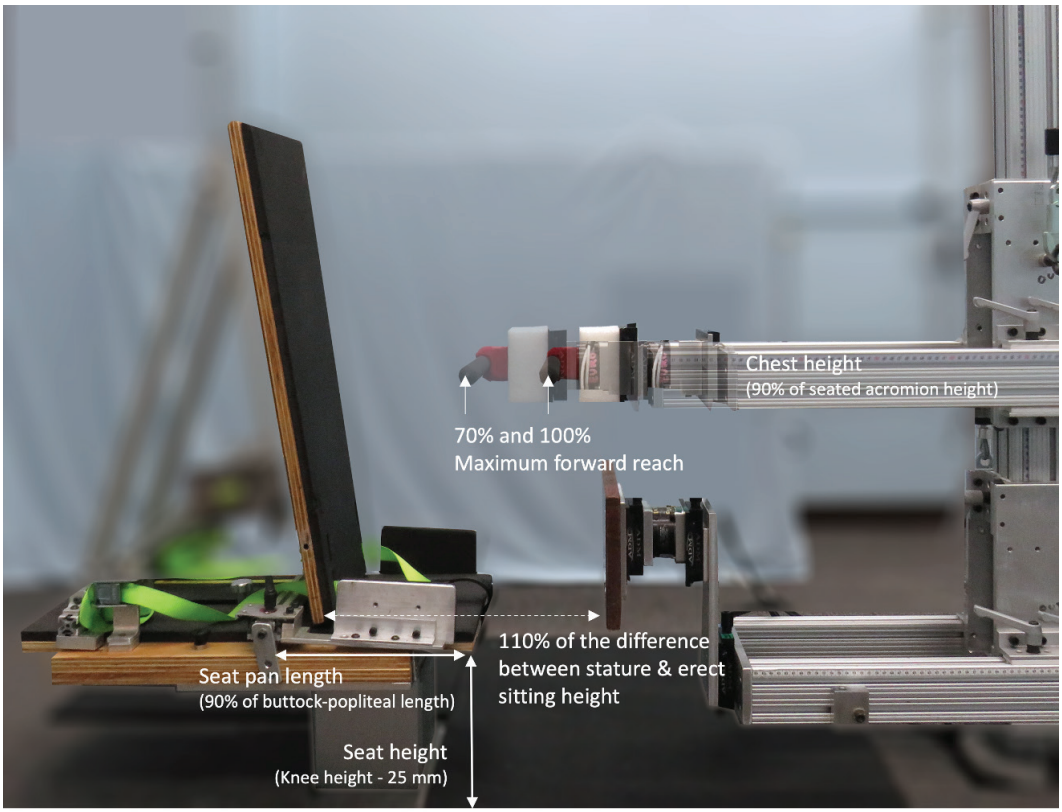

Figure 12. Illustration of 2H seated exertion configurations for the seated push and pull and foot push exertions scaled to a child with a stature of 800 mm.

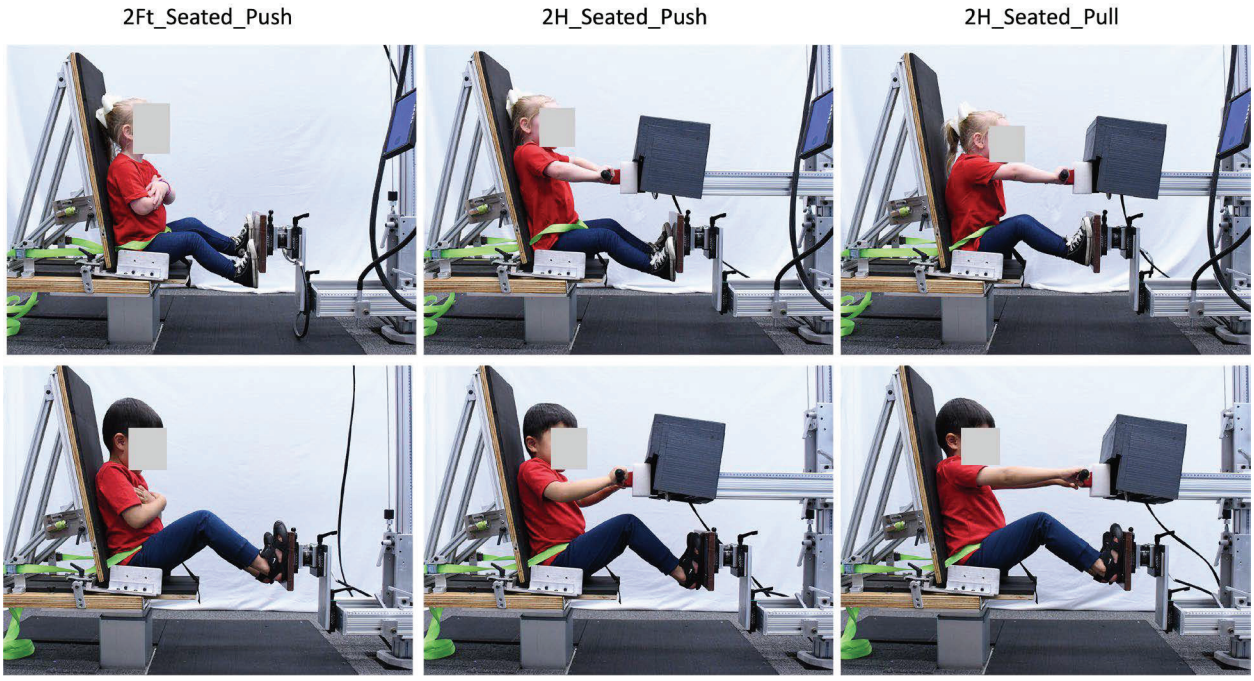

Figure 13. Representative 2H seated exertions (2F_Seated_Push, 2H_Seated_Push, 2H_Seated_Pull). The upper and lower images in each column show different children doing the same exertion. Note that the children depicted were not participating in the study; photos were staged for purposes of illustration.

For 1H seated tasks the seat was rotated 90-deg, so the child faced perpendicular relative to the horizontal components of the structure (Figure 14). For 1H seated push and pull tasks the interface vertical position was set to 90% of seated acromion height, approximately chest height. The horizontal distance between the seat and the 1H_Bar_Horz interface was set to 100% and 70% of the lateral grip reach from the seat centerline for pull and push tasks, defined by the difference between lateral grip reach and 50% of biacromial breadth. All measures were predicted from stature.

For 1H seated lift and push down tasks the interface vertical position was set to align with the height of the foam on the test seat. The horizontal position of the 1H_Bar_Horz interface was set laterally 245 mm from the seat centerline resulting in 45 mm clearance between the handle and the edge of the seat. The center of the handle was 70 mm forward of the rear edge of the seat. All measures were predicted from stature. Figure 15 shows photos of representative one-hand seated exertions.

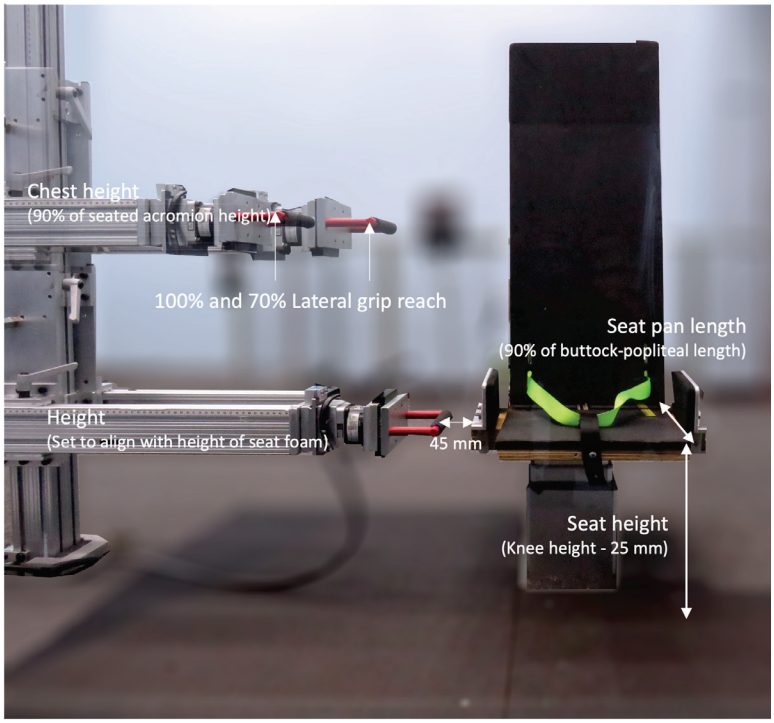

Figure 14. 1H seated exertion configurations for push/pull and lift/push down tasks scaled to a child with a stature of 800 mm.

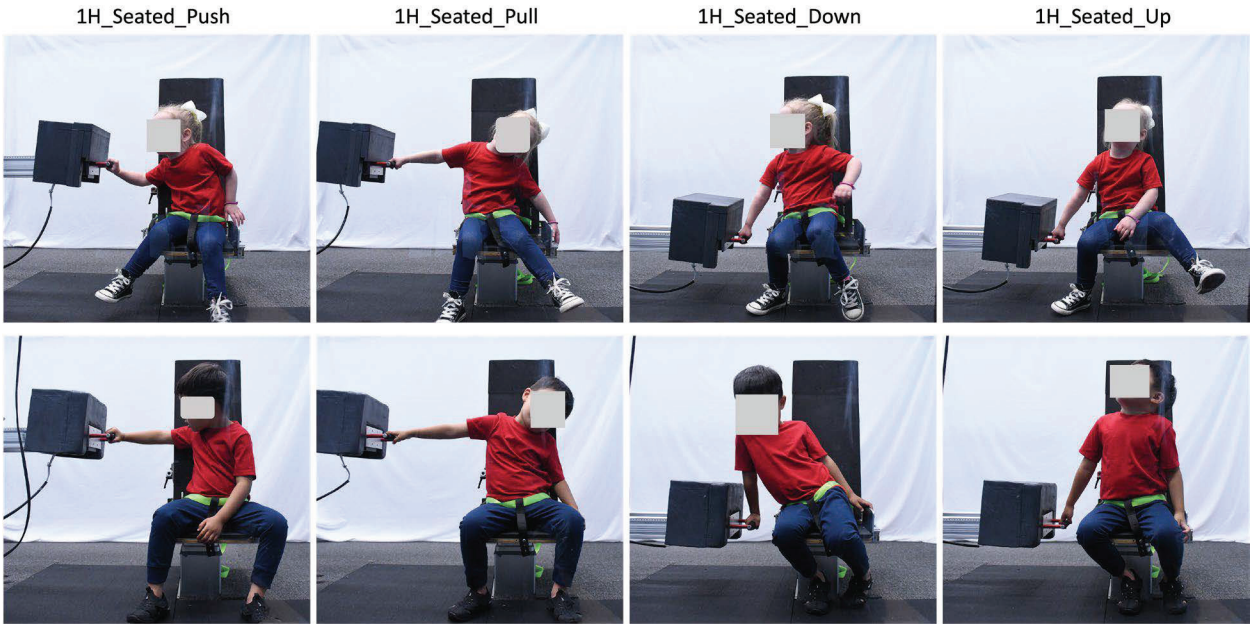

Figure 15. Representative 1H seated exertions (1H_Seated_Pull, 1H_Seated_Push, 1H_Seated_Down, 1H_Seated_Up). The upper and lower images in each column show different children doing the same exertion. Note that the children depicted were not participating in the study; photos were staged for purposes of illustration.

The number of exertion tasks for each child was balanced against considerations of attention, motivation, and fatigue. Because the list of measures of interest was too large for the allotted two-hour time window, the 1H and 2H seated and standing tasks were divided into two matrices, termed M1 and M2. Table 5 identifies the individual strength measures gathered in the M1 and M2 test matrices respectively. The order of conditions was varied to avoid loading up one part of the body consecutively. For example, a hand pull might be followed by a hand or foot push. Each child was randomly assigned to either the M1 or M2 matrix. Note that the hand and whole-body exertions were performed in both matrices. Children who did standing two-hand exertions were presented with one-hand seated conditions and vice-versa. Under certain circumstances, investigators modified the presentation order or skipped measures in response to safety and behavioral issues. For example, if a child was not keen to sit in the test chair, the seated measures were not attempted until the end of the session.

Table 5
M1 and M2 Matrices in Order of Presentation

M1 Matrix	**M2 Matrix**
1H_Shoulder_Push	2H_Shoulder_Push
1H_Shoulder_Pull	2H_Shoulder_Pull
1H_Shoulder_Up	2H_Shoulder_Up
Dynamometer_24mm_Elbow_Grip	Dynamometer_24mm_Elbow_Grip
1H_Elbow_Push	2H_Elbow_Push
1H_Elbow_Pull	2H_Elbow_Pull
1H_Elbow_Up	2H_Elbow_Up
FingerSurface_Index_Elbow_Push	FingerSurface_Index_Elbow_Push
FingerSurface_Thumb_Elbow_Push	FingerSurface_Thumb_Elbow_Push
TurnKnob_40mm_Elbow_CW	TurnKnob_40mm_Elbow_CW
2H_Seated_Pull	1H_Seated_Pull
2H_Seated_Push	1H_Seated_Push
2F_Seated_Push	1H_Seated_Up
1H_Thigh_Push	1H_Seated_Down
1H_Thigh_Pull	2H_Thigh_Push
1H_Thigh_Up	2H_Thigh_Pull
PullApart_HandCouple_Pull	2H_Thigh_Up
ShoulderPush_Elbow_Push	PullApart_HandCouple_Pull
PinchPull_19mm_Elbow_Pull	ShoulderPush_Elbow_Push
Dynamometer_24mm_Elbow_Grip	PinchPull_19mm_Elbow_Pull
1H_OverHead_Push	Dynamometer_24mm_Elbow_Grip
1H_OverHead_Pull	2H_OverHead_Push
	2H_OverHead_Pull

Data Collection Protocol

During all aspects of the functional strength protocol, safety considerations were given the highest priority. All study team members who interacted with minors participating as subjects completed comprehensive training modules focused on polices and issues related to the health, wellness, safety, and security of children, and consented to background checks. In adherence with best practices for research with children, all research staff interactions with children were witnessed by an adult third party. As such, caregivers were required to accompany their child throughout testing sessions, and a minimum of two research investigators were always present.

The children were required to perform each exertion task at least three times. For each trial, the child was encouraged to ramp up the exertion and hold at the maximal value for a three-second count. During each exertion task, the investigator counted the three second hold duration aloud.

The motivation environment was positive to enable continual engagement with the child. Interactions between the investigator and child participant were intentional and scripted to ensure reproducibility for the exertion tasks. Investigators were trained to speak in their natural voice, show enthusiasm, get down to the child participant's eye level and make eye contact, and to encourage the child with smiles, high-fives, and fist bumps. While interacting with the child participant, investigators listened attentively, asked honest questions, answered questions honestly, and gave specific feedback rather than continual praise. Excessive praise was avoided because it rapidly loses effectiveness in motivating the child. Importantly, this age cohort generally cannot respond consistently to verbal instructions that might be sufficient for adults. In consultation with child development experts on the team, and after considerable pilot testing, a visual feedback system was used in parallel with positive coaching and encouragement from the investigator and caregiver to motivate the child to increase force exertion.

Visual Force Feedback

Real-time force feedback was provided to the child using an animation displayed on a screen that was positioned approximately at eye height in the child's field of view. The feedback display consists of four parallel feedback elements shown in Figure 16. The previous maximum force for the child is represented by the height of a gray disk relative to the bottom of the screen. The force exerted in a current trial is represented by (1) the vertical position of a round yellow disk that is analogous to a face, (2) the width and curvature of the face's smile, and (3) the size of the face. The metaphor is a balloon: as the child exerts increasing force, the display adjusts in real time, with the face rising toward the target with higher force exertion. As the force on the requested axis ("on-axis") approaches the previous maximum force, the vertical height of the yellow disk and the size of the smile increase. Forces above the previous maximum force are represented by an increase in the size of the yellow disk. During a trial, if the force drops, the yellow disk representing the face stays at the peak for the current trial, while a light-yellow disk continues to follow the current force values. No feedback is provided to the subject for the initial trial of a specific exertion task to determine an estimate for the initial maximum exertion force. The maximum of the subsequent trials is scaled to the previous best effort to elicit higher force exertions.

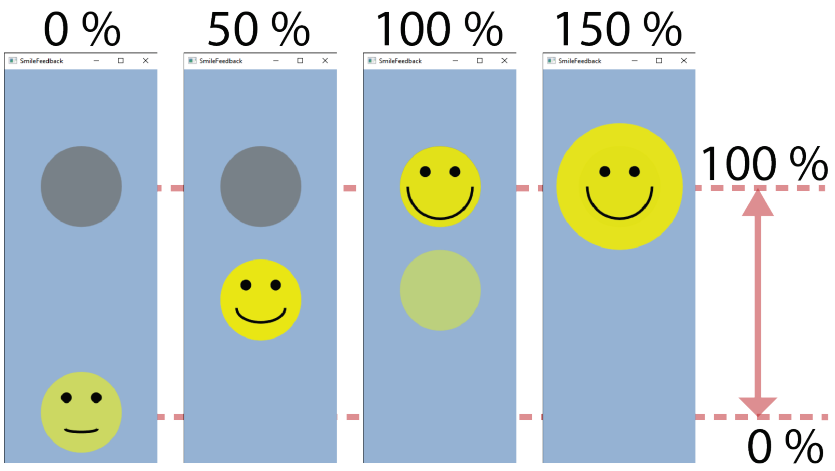

Figure 16. Force feedback display presented to the participant at 0%, 50%, 100%, and 150% of the individual's previous maximum force.

The number of trials performed depend on the capability and attention of the child, but the maximum duration of a child's participation was two hours. To minimize the effects of fatigue, five-minute breaks were taken as required or at least every 20 minutes to allow the child to relax and play. The grip strength measurement was conducted twice, once near the beginning and again at the conclusion of the task conditions to assess participant fatigue. Analysis of the grip strength data measures did not reveal any significant fatigue.

Data Acquisition and Analysis

Multiple cameras recorded the child participant performing each task and were used to assess the child's performance, particularly their tactics for achieving the requested exertions. Images were recorded at a rate of 15 Hz and a resolution of 640 x 576 pixels (Logitech C920) or 1280 x 720 pixels (Microsoft Azure Kinect). The specific number and type of cameras used varied by task. Additionally, multiple time-of-flight cameras (Microsoft Azure Kinect) were used to record 3D point clouds of the participant at a rate of 15 Hz and a resolution of 640 x 576 points.

The data from trials with young children are considerably more challenging to process and analyze than those from adults and older children who are able to follow instructions precisely. Video review of every trial was necessary to categorize the postures and to ensure that the force values were obtained in a valid trial. We developed a software interface that allowed investigators to step through the data, viewing the synchronized video and force histories. The software was used to identify time windows containing valid trials with respect to force direction and posture (e.g., the child must exert force independently with the requested one or two hands and at least one foot in contact with the floor). Figure 17 shows an example of the time-series data for a 2H standing push exertion. The central window with a white background is the portion of the data (event window) that the investigators selected as representing a valid trial, based on the hand force data and the child and caregiver behavior, confirmed from video of the trial.

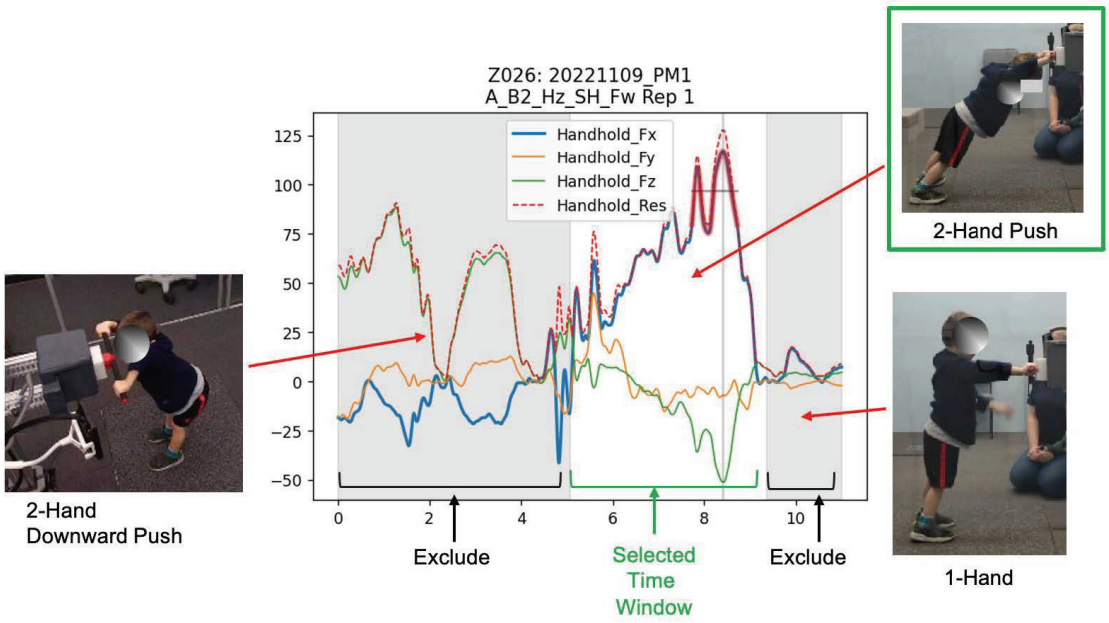

Figure 17. Data verification and window selection for a two-handed push exertion task.

To estimate the sustained force level, a one-second moving average was computed over the event window. In Figure 17, the portion of the force-time trace in red illustrates the data for which the moving average metric was at its maximum across the event window. This value was reported as the outcome for the trial. The summary tables in this document report the maximum of the one-second moving-average window as an approximation of maximum sustained force level, *i.e.*, strength.

Only the force value on the requested axis (*e.g.*, horizontal for pushes and pulls) was considered for the current analysis. Note that children usually exerted substantial force on other axes (for example, see the Fy and Fz traces Figure 17), so that the resultant force was generally higher than the on-axis force.

The analysis in this report is based on the maximum force observed in the available trials for each participant and measurement location. That is, only the result of a single trial for each participant is included in the analysis for each measure.

Participant Recruitment, Screening, and Consent

Participants were recruited via their caregivers through the University of Michigan Clinical Health Studies website, flyers posted at local childcare facilities, schools, and community centers, social media, and online community bulletin and interest groups. Child participants and their caregivers came to the laboratory and the procedures were reviewed with the caregivers.

Inclusion criteria for the strength study protocol included children ages 24 through 71 months. The children must have normal physical and cognitive development to participate in the study. Caregivers were also asked to report if their child was able to follow instructions. These assessments were determined based upon self-reports provided by caregivers during the recruitment process.

Two research investigators initially greeted and introduced the study, one focusing on the caregiver and one to support the child. The procedures were explained and demonstrated using age-appropriate language and methods to both the caregiver and child (e.g., play-based interaction). Written informed consent was obtained using procedures approved by the Health Sciences and Behavioral Sciences Institutional Review Board at the University of Michigan. Oral assent was obtained from children older than 18 months who demonstrated ability to verbally communicate. For children younger than 18 months or who demonstrated a lack of ability to communicate verbally the caregiver was asked to provide verbal consent in the presence of the child participant.

In total 400 children participated in the study. Table 6 lists the number of children in each age group by gender. Male participants were 58% of the total.

Table 6
Summary of the Number of Participants by Age Group and Gender

Age Group	Total	Female	Male
24 – 29 months	85	33	52
30 – 35 months	94	45	49
36 – 47 months	81	33	48
48 – 59 months	71	26	45
60 – 71 months	69	30	39
	400	167	233

Reasons for Dropouts or Failure to Complete

Strength measures were not obtained in some cases due to a range of issues. Among the possible status outcomes of an attempt to complete the strength protocol were as follows:

1) *Completed*: Strength measures were completed successfully.
2) *Skipped*: The strength measure was not completed for reasons associated with a child inability or willingness to focus or if the investigators ran out of appointment time to complete the bite protocol.
3) *Attempted*: A strength measure was attempted; however, the child exerted negligible force, the child would not engage in the protocol, demonstrated an inability to listen or comprehend the task instructions or what was being asked of them, or could not complete all three repetitions.
4) *Refused:* Child or caregiver refused to complete a strength measure.

Participant Characteristics: Anthropometric Measurements

Measurement Considerations

Table 7 lists the anthropometric measures of interest for the study. During pilot testing it became apparent that it was not feasible to take all of these measurements manually. Two considerations were paramount. First, the measurement time was substantial, more than 15 minutes in some cases, because the children had a hard time sitting or standing still for the measurement. Second, the need to stand still for the measurement was not conducive to the playful attitude and focus that were needed for the strength measurements. That is, taking the anthropometric measures first tended to make the child unwilling to continue to participate in the strength measurement. Taking the measurements at the end was also not feasible because the child was typically tired by that point and unwilling to assume and hold the specified postures.

Consequently, in consultation with CPSC staff, we developed an alternative approach to characterizing the participant body size and shape. We drew on extensive experience with 3D body shape measurement and modeling to develop a hybrid approach in which we used direct measurement for the most important variables and used statistical modeling based on high-resolution, whole-body laser scan data to compute the remaining variables of interest. In certain cases, we also drew on detailed measurements obtained in the Snyder et al. (1977) child anthropometry study. The following paragraphs describe the methods listed in Table 7.

Table 7
Anthropometric Dimensions, Data Sources, and Methods

Requested Dimension	Reported Name	Method	Notes
Stature	Stature	Direct measurement	Snyder methods[a]
Weight	Weight	Direct measurement	Snyder methods
--	Sitting Height	Direct measurement	Snyder methods
Shoulder Height, Seated	Acromial Height, Seated	Direct measurement	Snyder methods
Shoulder Height, Standing	Acromial Height, Standing	Computed **	
Shoulder Breadth	Shoulder (Bideltoid) Breadth	3D Scan Modeling	
Hip Breadth	Hip Breadth, Standing	3D Scan Modeling	
Elbow Height, Standing	Elbow Height, Standing	3D Scan Modeling	Landmark-based†
Elbow Height, Seated	Elbow Height, Seated	3D Scan Modeling	Landmark-based
Arm length to fingertips	Elbow-fingertip Length	3D Scan Modeling	
Arm length to grip	Elbow-grip Length	3D Scan Modeling	
Upper arm length	Shoulder-Elbow Length	3D Scan Modeling	
Lower arm length	Elbow-Wrist Length	3D Scan Modeling	
Hand Length	Hand Length	3D Scan Modeling	Snyder data*
Hand Breadth, Palm	Hand Breadth	3D Scan Modeling	Snyder data *
Hand Breadth, Thumb	Hand Breadth with Thumb	3D Scan Modeling	Snyder data***
Ankle Height	Ankle (Lat. Malleolus) Height	3D Scan Modeling	Landmark-based
Foot Length	Foot Length	3D Scan Modeling	Snyder*
Foot Breadth	Foot Breadth	3D Scan Modeling	Snyder*

[a] Methods equivalent to Snyder et al. (1977)
* Snyder et al. (1977) data used to add these measures to the UMTRI 3D dataset.
** Computed by subtracting delta between erect sitting height and seated acromion height from stature
*** Derived measured obtained by adding thumb diameter to hand breadth
† Landmark-based dimensions were computed from landmarks in the UMTRI 3D dataset before 3D scan modeling.

Direct Measurement

The most important anthropometric variables (stature, body weight, erect sitting height, and acromial height) were measured directly using techniques adapted from Snyder et al. (1977). Stature was measured with and without shoes using an anthropometer. Erect sitting height and seated acromial height were measured using an anthropometer with the child seated erect on a flat measurement surface.

3D Scan Modeling

Because manual measurement was not practical for all dimensions, due to time constraints and child behavior, a methodology based on 3D scan modeling was conducted. A VITUS XXL laser scanner was used to capture whole-body size and shape for the clothed child in a standing "A" pose with the upper extremities slightly abducted. Figure 18 shows a child in the scanner.

Figure 18. Child in the 3D scanner (staged photo).

The standing scan data for each participant were fit using a statistical body shape model developed in prior UMTRI work (Park et al. 2015). In that study, 150 children ages 3 through 11 years were scanned in a standing posture while minimally clad and a variety of manual anthropometric measures were taken. A statistical body shape model was created by fitting the scan data with a homologous template and conducting principal component analysis (PCA) on the template vertex locations. This statistical model was used in the current study to obtain body dimensions. (A version of this statistical model is available online at http://HumanShape.org/.)

The fitting process first aligns the scan to the model coordinate system and then performs an optimization to find the body size and shape in the space of the statistical shape model that best matches the data. This results in a set of 20 shape descriptors (principal component scores) that describe the child's size, shape, and posture. This method generates accurate body shapes for the clothed scans obtained in this study. Figure 19 shows several template fits, demonstrating the capability to obtain a valid avatar with widely varying clothing and posture.

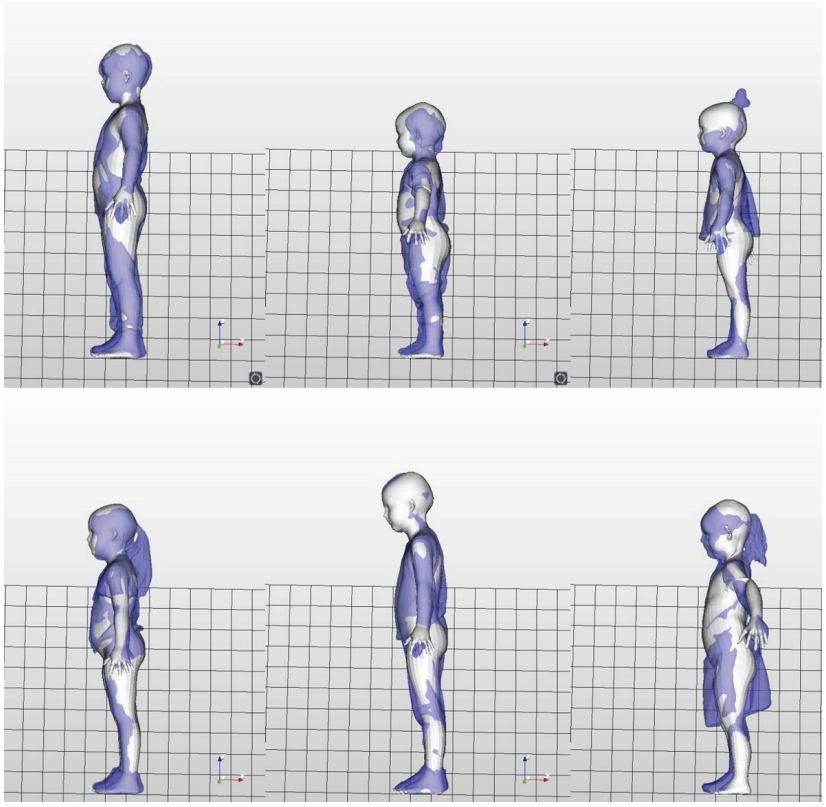

Figure 19. Examples of fitted data, demonstrating the avatar fit (white) to clothed scans (purple) for children with a range of body size.

Using data from the original anthropometry study (Park et al. 2015), a regression model was created that predicts manually measured body dimensions from the principal component scores. This prediction methodology incorporates random sampling from the regression residuals so that the population variance on each measure is maintained.

For two variables, additional data were extracted from scan data to obtain the desired dimensions. Elbow height was not measured in the original UMTRI study, but a 3D landmark location at the elbow was recorded on the scans. The height of this landmark in the 3D scan fits was used as standing elbow height. To estimate seated elbow height, the difference between stature and elbow standing height was subtracted from sitting height. Ankle height was similarly obtained from a landmark (lateral malleolus) in the 3D scan fits. Missing data were imputed using regression with random sampling of residual variance.

Other dimensions not available in the original UMTRI dataset (see Table 7) were imputed using a principal component analysis and regression (PCAR) based on data from Snyder et al. (1977). PCA was performed on variables of interest extracted from the Snyder dataset for children ages 3-11. A regression based on stature and body weight was used to predict principal component scores, incorporating a random resampling of residual variance from the regressions. The scores were clamped to lie within the observed range to avoid extreme values from the random residual

sampling. For hand breadth with thumb, the thumb diameter was added to hand breadth in the Snyder data to obtain the measure.

This 3D scan analysis method was successful for 349 of 399 children with available anthropometric data. For the remaining children, the scan quality was not sufficient to accurately fit the avatar, so variables were estimated using the same PCAR method used to obtain values from the Snyder data. That is, a PCAR analysis was conducted on the outcome measures for the 349 fitted children. The predictions based on stature and body weight incorporated residual variance with clamped PC scores.

Summary Statistics

Table 8 and Table 9 show summary statistics for stature and body weight by gender and age group for all participants. Summary statistics for all anthropometric measures are tabulated in Appendix C.

Table 8
Participant Stature (mm)

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	56	870	38	693	831	868	926	945
24-29	2.00-2.49	F	33	852	35	775	805	841	900	923
24-29	2.00-2.49	Both	89	863	38	693	817	861	921	945
30-35	2.50-2.99	M	48	934	47	827	867	940	993	1077
30-35	2.50-2.99	F	43	898	37	813	841	894	971	975
30-35	2.50-2.99	Both	91	917	46	813	852	914	988	1077
36-47	3.00-3.99	M	48	995	51	901	913	996	1063	1143
36-47	3.00-3.99	F	31	981	38	905	912	982	1038	1045
36-47	3.00-3.99	Both	79	990	46	901	906	986	1058	1143
48-59	4.00-4.99	M	45	1046	51	869	981	1052	1129	1142
48-59	4.00-4.99	F	26	1054	30	999	1010	1058	1103	1110
48-59	4.00-4.99	Both	71	1049	44	869	984	1053	1112	1142
60-71	5.00-5.99	M	39	1128	51	1051	1056	1120	1207	1219
60-71	5.00-5.99	F	30	1104	43	1029	1037	1096	1169	1194
60-71	5.00-5.99	Both	69	1118	49	1029	1048	1107	1201	1219

Table 9
Participant Body Weight (kg)

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	56	13	1	8	11	13	15	17
24-29	2.00-2.49	F	33	12	1	10	10	12	15	16
24-29	2.00-2.49	Both	89	13	1	8	11	13	15	17
30-35	2.50-2.99	M	48	15	2	11	13	15	18	20
30-35	2.50-2.99	F	43	14	2	10	11	14	18	22
30-35	2.50-2.99	Both	91	14	2	10	12	14	18	22
36-47	3.00-3.99	M	48	16	2	13	14	16	19	21
36-47	3.00-3.99	F	31	15	2	13	13	15	18	19
36-47	3.00-3.99	Both	79	16	2	13	13	16	19	21
48-59	4.00-4.99	M	45	18	3	14	14	17	23	24
48-59	4.00-4.99	F	26	17	2	15	15	17	20	22
48-59	4.00-4.99	Both	71	18	2	14	14	17	23	24
60-71	5.00-5.99	M	39	21	3	17	17	20	26	29
60-71	5.00-5.99	F	30	19	3	14	16	19	24	25
60-71	5.00-5.99	Both	69	20	3	14	16	20	25	29

RESULTS

Summary Statistics

For each measure (*e.g.*, one-hand standing push at elbow height), the mean, standard deviation, and a range of quantiles are presented. Table 10 shows an example summary, listing outcomes for boys, girls, and the combined population by age group. Appendix D provides summaries for all measures.

Table 10
1H_Elbow_Pull: One-hand Standing Pull at Elbow Height (N)

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	25	28.3	13.9	2.8	10.6	29.4	50.4	57.0
24-29	2.00-2.49	F	13	20.5	10.7	1.6	6.3	20.2	37.3	39.4
24-29	2.00-2.49	Both	38	25.6	13.3	1.6	8.5	23.8	48.5	57.0
30-35	2.50-2.99	M	24	42.7	11.9	20.7	26.5	41.7	62.2	67.0
30-35	2.50-2.99	F	23	42.8	15.6	8.8	11.1	43.4	61.3	71.4
30-35	2.50-2.99	Both	47	42.8	13.7	8.8	21.1	43.1	62.6	71.4
36-47	3.00-3.99	M	22	64.1	25.4	6.3	18.2	71.8	94.9	96.6
36-47	3.00-3.99	F	17	53.1	15.1	30.4	31.5	53.2	79.5	89.4
36-47	3.00-3.99	Both	39	59.3	22.0	6.3	22.7	55.9	94.9	96.6
48-59	4.00-4.99	M	22	89.8	28.9	44.2	46.4	88.4	144.7	148.2
48-59	4.00-4.99	F	12	83.0	15.3	59.9	60.8	87.4	103.2	104.5
48-59	4.00-4.99	Both	34	87.4	24.9	44.2	49.7	88.4	137.4	148.2
60-71	5.00-5.99	M	18	112.7	25.8	59.3	78.3	109.1	158.9	161.6
60-71	5.00-5.99	F	15	96.3	24.9	60.3	66.6	95.3	136.1	152.0
60-71	5.00-5.99	Both	33	105.2	26.3	59.3	65.7	102.9	154.5	161.6

DISCUSSION

Key Findings from the Study

The data show a strong and approximately linear effect of age on force generation under these conditions. The mean force for boys was somewhat higher for some exertions, although no statistical tests were conducted because analysis of covariate effects was out of scope for this data collection effort. Because stature and body weight are well correlated with age in this cohort, the relationship with either variable is similar to the relationship with age.

Consistent with prior studies, the strength values were highly variable even within age groups. The standard deviation was typically 25 to 50% of the mean value. Some of the variability is undoubtedly due to physical differences among children, but, although the effects of motivation and attention were observed during data collection, they cannot be easily quantified. A minimum of three trials were performed for each condition, and the maximum used for analysis, so training effects should be minimal. No evidence of child fatigue was found in the repeated grip strength measure, but the large amount of variability makes that difficult to assess.

The data provide clear evidence of forces that children in these age groups are capable of exerting under the prescribed conditions. The upper quantiles likely represent actual strength values, *i.e.*, values close to the maximum that these children could produce. However, the lower quantiles should not be interpreted as maximum values for children with lower strength, because it is likely that many of the measured exertions were submaximal.

Lessons Learned

A large amount of pilot testing was conducted to develop the methods used in this study. Important lessons learned during the pilot and full-scale testing include:

- The caregiver is an integral part of the measurement protocol. Encouragement and support from the caregiver can have strong effects on the results, particularly for the younger children.
- Careful training of the investigators and scripting of the interactions are essential to reproducible data collection.
- Some of the younger children in this cohort (24 through 35 months old) have a difficult time interpreting the request for a maximal sustained exertion. The level of motor development varied considerably among children, so that some were much better at organizing their postures to biomechanical advantage. Consistent coaching from the investigator is essential to obtain good data from these children.

- Ensuring that the environment is fun and engaging, but not distracting, is essential with these young children. Frequent breaks were needed, and flexibility with respect to the test sequence was necessary to accommodate the fluctuating interest of the child.

Implications and Shortcomings

The study is limited by the sample size, although it is among the largest strength studies that have been conducted with children in this age range. This study used a convenience sample of children and their caregivers from the Ann Arbor area in Southeast Michigan. The results may not be applicable to other populations. All children were reported by their caregivers to have normal development, but no effort was made to verify either cognitive or physical development. Nonetheless, no children with known developmental delays or physical disabilities were included in the sample, which limits the applicability of the results.

The findings are also limited by the measurement methods, which include all aspects of the test protocol and environment. Data were gathered during a two-hour laboratory session that included a wide range of tasks and measurements, including manual anthropometry and body scanning. Some children experienced a substantial decline in engagement and motivation during the study. Due to the challenges of balancing the time required to adjust the laboratory fixtures and the desire to minimize fatigue, the test conditions in each of the M1 and M2 matrices were typically presented in the same order, which may have introduced some order effects. However, the nature of these effects is unknown: some children seemed to "warm up" and get more engaged through the data collection, while the attention of other children waned over the session. Hence, we do not believe that the order effects are important.

The tasks and particularly the interfaces were designed to elicit high forces. In particular, the interfaces were padded and contoured to reduce the possibility that discomfort at the interface would limit the child's willingness to exert force. The participants wore their own comfortable clothing and shoes and stood or sat on high-friction surfaces. The pinch-pull condition is an exception: the interface is composed of smooth aluminum that presents a somewhat low-friction interface. The parallel pads necessitate a relatively large amount of normal force (pinching) to enable the pull force, which is sustained through friction between the measurement pads and the child's fingers and thumb. Due to the nature of the interface, these forces should be regarded as a low estimate of the forces that children could exert in a pinch-pull scenario with a higher friction or contoured interface.

The visual force feedback system was an integral part of the measurement method, and measurements made with the same apparatus, but different feedback, could potentially be substantially different. This system was developed in consultation with child development experts and through extensive pilot testing. The method incorporated an

adaptive feedback system so that each child was encouraged to exceed their personal best in the current condition, rather than being evaluated against an external standard.

The children in this study were generally not able to sustain force with low variability for multiple seconds, so these results do not have the character of typical adult strength data, for which the mean of a three-second hold is often used. To address the temporal variability, the mean of a one-second moving average was used as the dependent measure, and the peak value of this moving average from each trial was selected as the "strength" metric. Using a different computational approach would result in different values.

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APPENDIX A: Load Cell Configurations

The following tables specify the load cells used in each condition by matrix.

Table A1
Load Cell Manufacturer, Model, and Capacity

			Capacity*					
Code	Mfr	Model	Fx (N)	Fy (N)	Fz (N)	Mx (Nm)	My (Nm)	Mz (Nm)
A	AMTI	MC3A-6-1000	2200	2200	4400	110	110	56
B	AMTI	OR6-7-1000	225	225	4450	1130	1130	565
C	Interface	WMC-100	445					
D	Interface	WMC-250	1112					
E	Denton	3300	12000	12000	14000	450	450	300

* Rated maximum full-scale force on three orthogonal axes (Fx, Fy, and Fz) along with the maximum rated moment around those axes (Mx, My, Mz). The data in this report were gathered on the Fx axis (horizontal pushes and pulls), and the Fz axis (push/pull up/down). Twist exertions were recorded on the Mx axis.

Table A2
Load Cell Configuration by Condition Group

Group	Direction	Primary*	Secondary	Floor**
Standing Exertions	Push/Pull/Up/Down	A		B
Power grip	Grip	C		
Finger/Thumb Push	Push	A		B
Pull Apart	Abduct	D		
Pinch and Pull	Pull	A	C	B
Shoulder Push	Push	A		B
Knob	Clockwise	A		B
Seat 2-Hand with Feet Up	Push	E		
Seat 2-Hand Pull w/ **Feet Push**	Pull	E	E	
Seat **FEET** Push, **NO HAND**	Push	E		

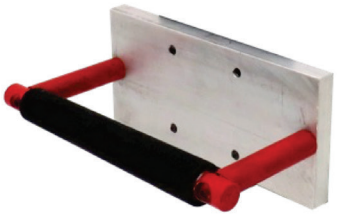
* Refer to Table A1 for definition of letter codes.
** Data from the force plate in the floor were gathered but not used for this report.

APPENDIX B: Force Interfaces

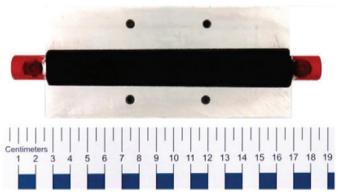
This appendix contains detailed specifications for the interfaces against which the children exerted forces. Photos, dimensions, and materials are provided.

1H_Bar_Horz

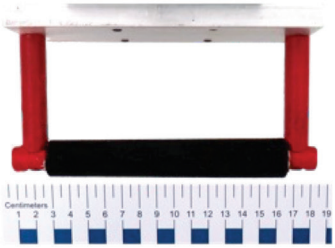
Cylindrical horizontal bar, 139 mm long and 21 mm in diameter, attached to a six-axis load cell. The bar was coated in vinyl foam that provided a high-friction grip.



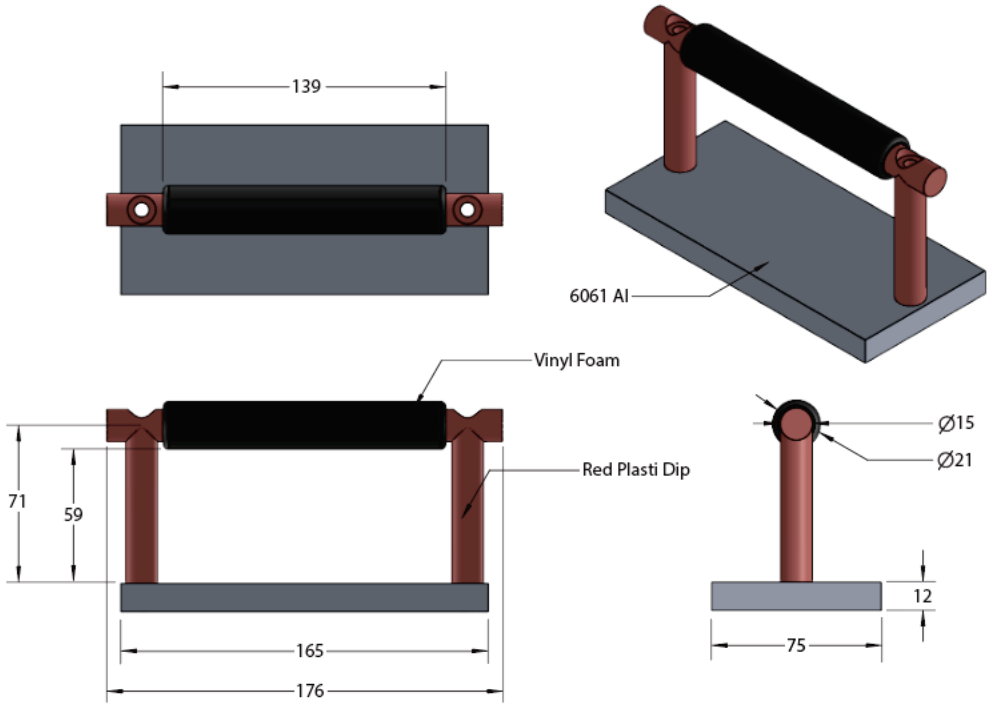
Oblique



Front



Top

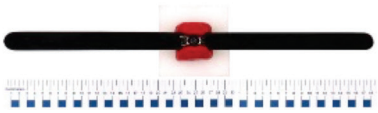


METRIC	UMTRI			TITLE: 1H_Bar_Horz	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MM	MODEL: A.L.	DRAWN: A.L.	PART NO:		
TOLERANCES	REV	INIT	DATE	MATERIAL: 6061 Al, Vinyl Foam, Plasti Dip	
	Initial Release	A.L.	2023/05/23		
	1	A.L.	2023/06/27	SCALE: 1:2	REV: 3
	2	A.L.	2023/07/24	WEIGHT: 0.6 kg	
	3	A.L.	2023/07/27	SHEET 1 OF 1	

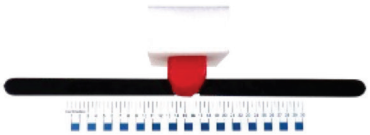
2H_Bar_Horz

Cylindrical horizontal T-bar, 475 mm long and 21 mm in diameter, attached to a six-axis load cell. The handle was coated in vinyl foam that provided a high-friction grip.

Oblique



Front



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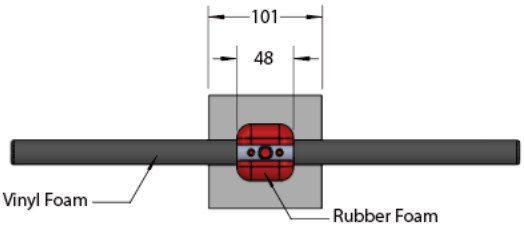
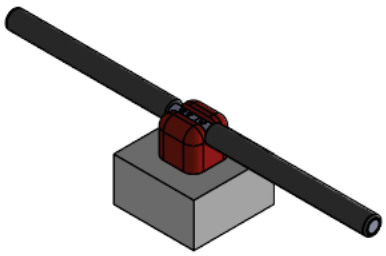
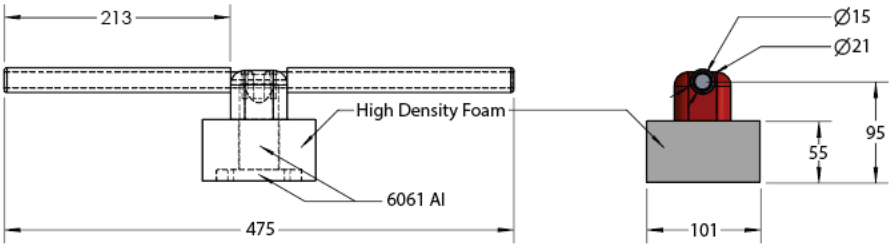


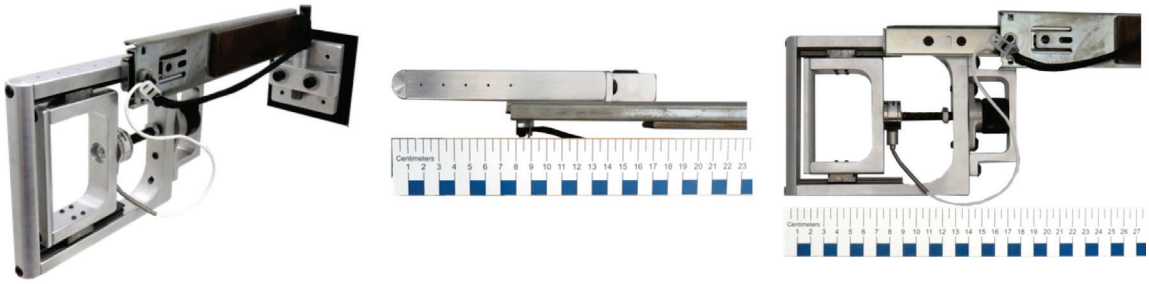




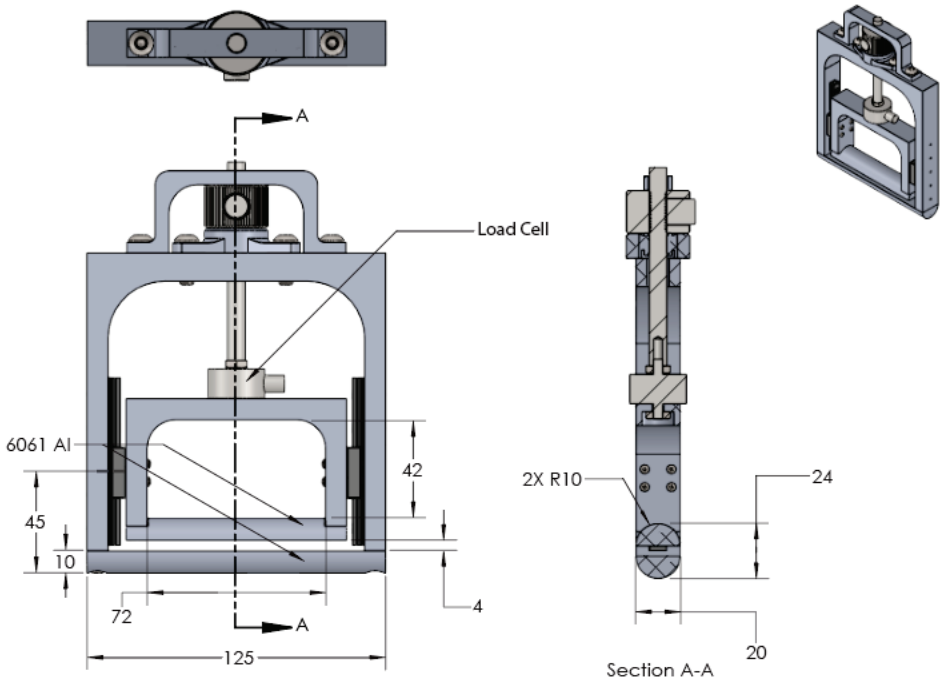
METRIC	UMTRI			TITLE: 2H_Bar_Horz		
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MM	MODEL: K.P.	DRAWN: A.L.	PART NO:			
TOLERANCES	REV	INIT	DATE	MATERIAL: 6061 Al, Foam		
	Initial Release	A.L.	2023/05/24			
	1	A.L.	2023/06/28	SCALE: 1:4	REV: 2	WEIGHT: 0.75 kg
	2	A.L.	2023/07/27			SHEET 1 OF 1

Dynamometer_24

Custom hand grip dynamometer with the aperture adjusted to 24 mm. A uniaxial load cell was integrated within the fixture. The handle was fabricated with 6061 aluminum alloy. The dynamometer was mounted on a low-friction slide that supported the instrument vertically but did not allow application of horizontal force.



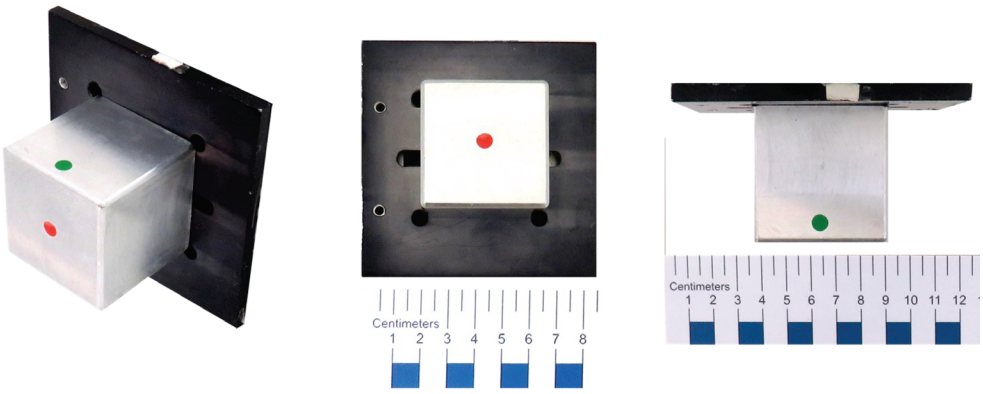
Oblique Top Side



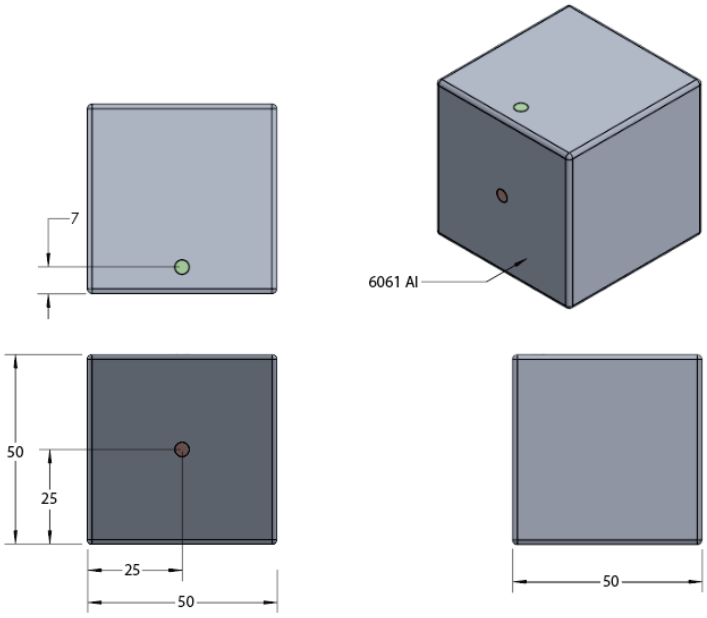
METRIC	UMTRI			TITLE: Dynamometer		
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MM	MODEL: K.B.	DRAWN: A.L.	PART NO:			
TOLERANCES	REV	INIT	DATE	MATERIAL: 6061 Al		
	Initial Release	A.L.	2023/06/09			
	1	A.L.	2023/06/29	SCALE: 1:2	REV: 2	WEIGHT: 0.7 kg
	2	A.L.	2023/07/27			SHEET 1 OF 1

FingerSurface

Finger surface interface (50 mm x 50 mm), attached to a six-axis load cell. Point of force application was visually indicated to child participant at the center of the finger surface (centered 25 mm from edge). The finger surface was fabricated with 6061 aluminum alloy.



Oblique Front Top

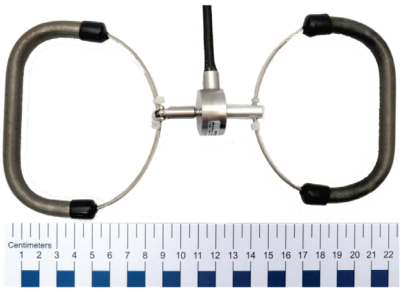


METRIC	UMTRI			TITLE: HandBlock		
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MM	MODEL: A.L.	DRAWN: A.L.	PART NO:			
TOLERANCES	REV	INIT	DATE	MATERIAL: 6061 Al		
	Initial Release	A.L.	2023/06/07			
	1	A.L.	2023/06/28	SCALE: 1:1	REV: 2	WEIGHT: 0.3 kg
	2	A.L.	2023/07/27			SHEET 1 OF 1

PullApart_HandCouple

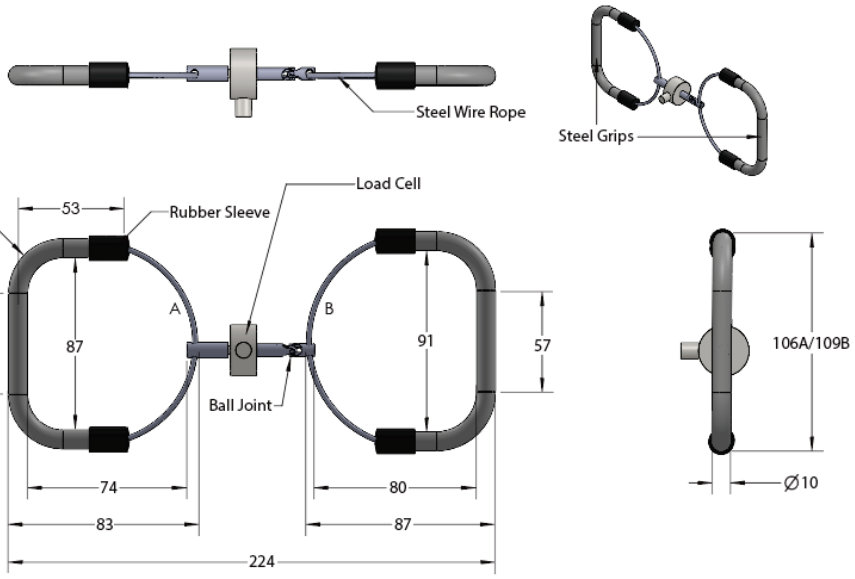
Asymmetric steel hand hold grips 10 mm in diameter with 54 mm and 57 mm lengths for hand coupling. A uniaxial load cell was integrated in the ball joint between the two hand grips.

Oblique



Front

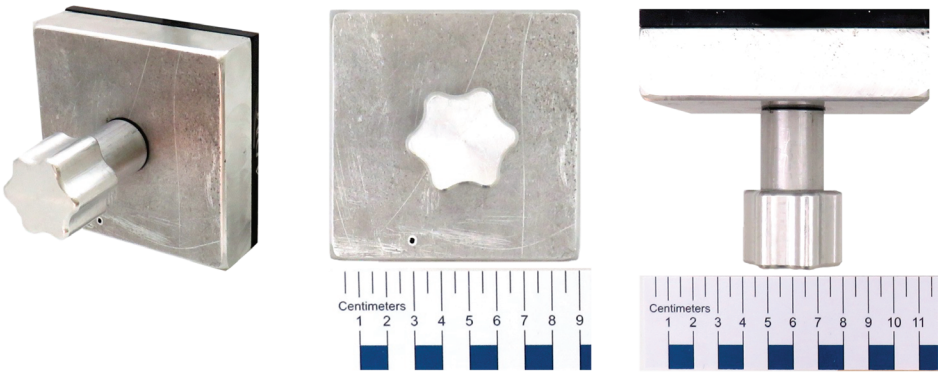
Side



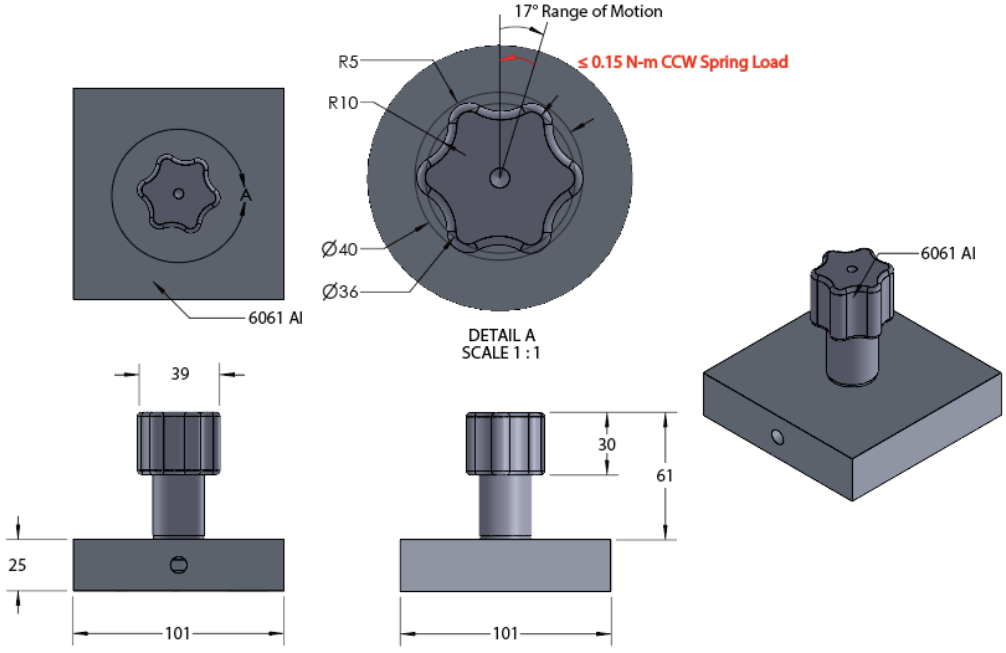
METRIC	UMTRI			TITLE: PullApart		
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MM	MODEL: A.L.	DRAWN: A.L.	PART NO:			
TOLERANCES	REV	INIT	DATE	MATERIAL: Steel, Steel Wire Rope, Rubber		
	Initial Release	A.L.	2023/06/07			
	1	A.L.	2023/06/29	SCALE: 1:2	REV: 3	WEIGHT: 0.16 kg
	2	A.L.	2023/07/27			SHEET 1 OF 1
	3	A.L.	2023/07/28			

TurnKnob_40

Fluted hexagon radiused knob with 5 mm radii and 40 mm outer diameter, attached to a six-axis load cell. The turn knob was fabricated with 6061 aluminum alloy and accommodated 17 degrees of spring-loaded, clockwise rotation.



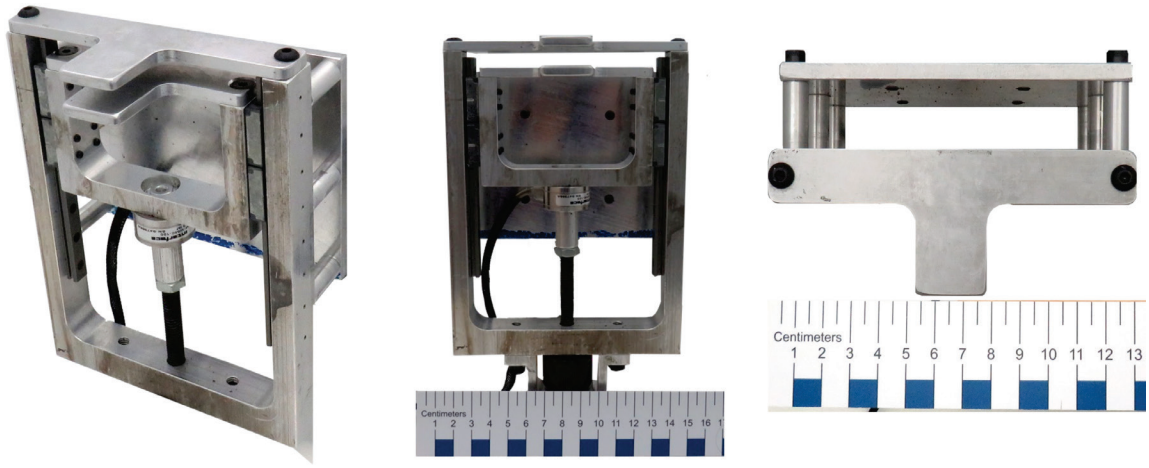
Oblique Front Top



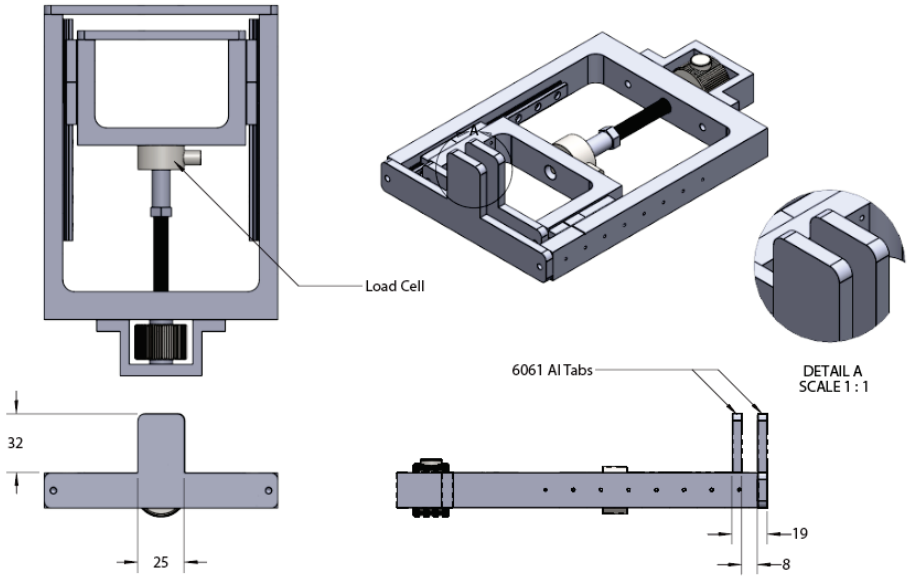
METRIC	UMTRI			TITLE: TurnKnob
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MM	MODEL: A.L.	DRAWN: A.L.	PART NO:	
TOLERANCES	REV	INIT	DATE	MATERIAL: 6061 Al
	Initial Release	A.L.	2023/06/07	
	1	A.L.	2023/06/28	SCALE: 1:2 / REV: 3 / WEIGHT: 0.8 kg
	2	A.L.	2023/07/27	
	3	A.L.	2023/07/31	SHEET 1 OF 1

PinchPull_19

Custom pinch pull fixture with tab interface aperture adjusted to 19 mm. A uniaxial load was integrated within the fixture to measure pinch force and the fixture was attached to a six-axis load cell to measure the pull force. The handle was fabricated with 6061 aluminum alloy.



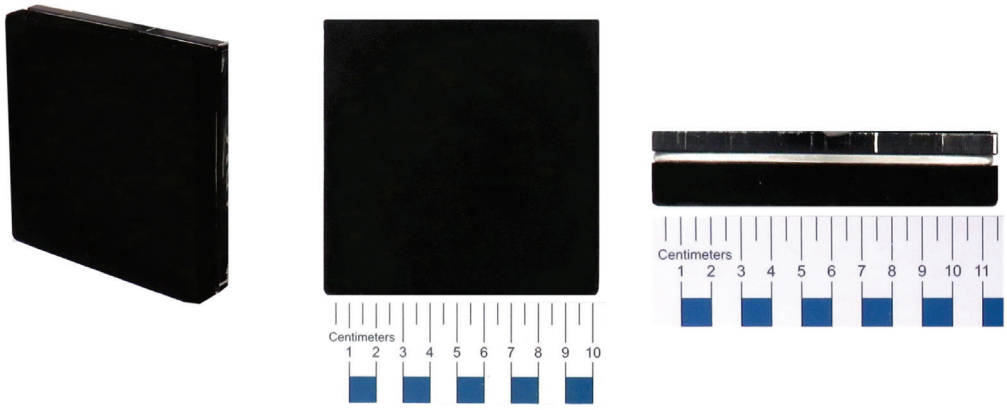
Oblique Front Top



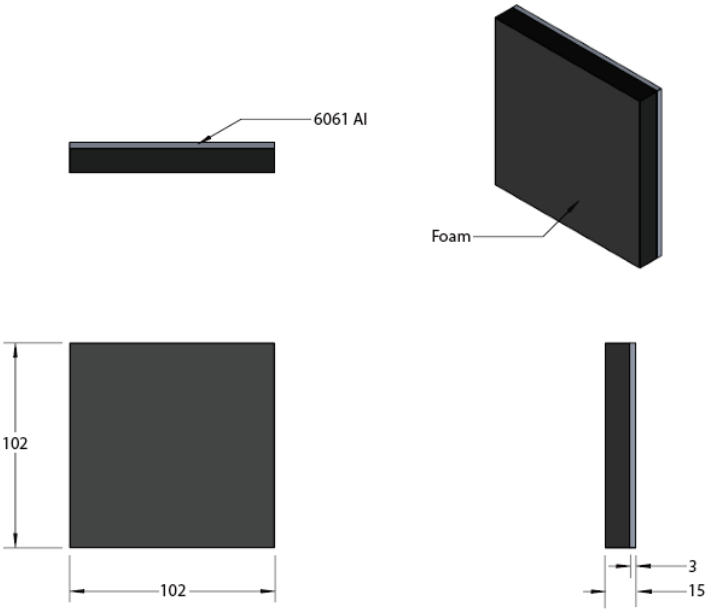
METRIC	UMTRI			TITLE: PinchPull		
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MM	MODEL: A.L.	DRAWN: A.L.	PART NO:			
TOLERANCES	REV	INIT	DATE	MATERIAL: 6061 Al		
	Initial Release	A.L.	2023/06/16			
	1	A.L.	2023/06/29	SCALE: 1:2	REV: 3	WEIGHT: 0.66 kg
	2	A.L.	2023/07/27			SHEET 1 OF 1
	3	A.L.	2023/07/31			

SquarePad

Square planar surface (102 mm x 102 mm), attached to a six-axis load cell. Plate is fabricated with 6061 aluminum alloy and covered with 12 mm of high-density foam.



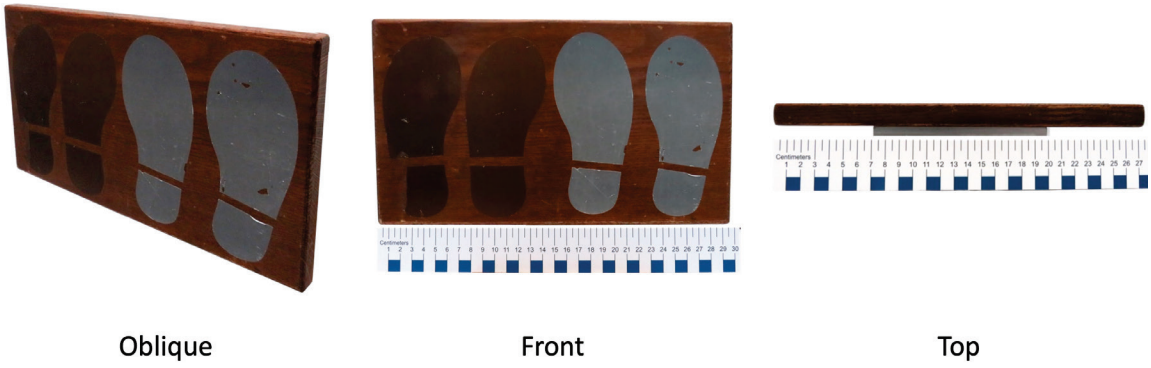
Oblique Front Side



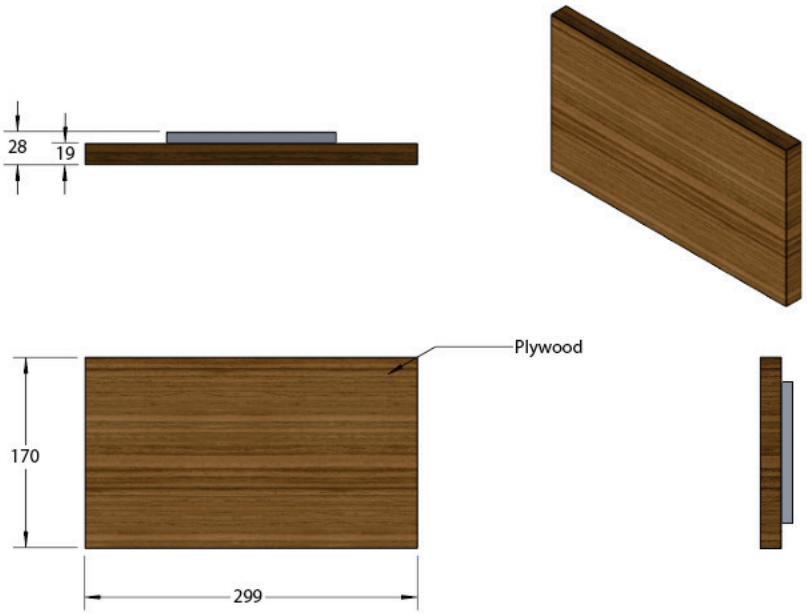
METRIC	UMTRI			TITLE: SquarePad		
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MM	MODEL: A.L.	DRAWN: A.L.	PART NO:			
TOLERANCES	REV	INIT	DATE	MATERIAL: 6061 Al, EPDM Foam*		
	Initial Release	A.L.	2023/06/07	SCALE: 1:2	REV: 2	WEIGHT: 0.1 kg
	1	A.L.	2023/06/28			SHEET 1 OF 1
	2	A.L.	2023/07/27			
*ethylene propylene diene terpolymer						

FootPush

A plywood surface (299 mm by 170 mm), attached to a six-axis load cell. Footprints on the planar surface provide a visual indicator for participants to place their feet.



Oblique Front Top



METRIC	UMTRI			TITLE: FootPush	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MM	MODEL: A.L.	DRAWN: A.L.	PART NO:		
TOLERANCES	REV	INIT	DATE	MATERIAL: Plywood, 6061 Al	
	Initial Release	A.L.	2023/06/08		
	1	A.L.	2023/06/29	SCALE: 1:4	REV: 2
	2	A.L.	2023/07/27	WEIGHT: 1.1 kg	
				SHEET 1 OF 1	

APPENDIX C: Summary Statistics for Body Dimensions

This appendix contains tables of summary statistics for body dimensions of the participants. The body of the report describes the measurement and calculation procedures. Of the values reported here, only stature, body weight, erect sitting height, and seated acromion (shoulder) height were directly measured. The remaining were estimated using several statistical methods, primarily based on 3D scans of the clothed participants. These values should not be considered as definitive quantification of body dimensions of children in these age cohorts, but rather provide a description of this sample of children.

Stature

Units: mm

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	56	870	38	693	831	868	926	945
24-29	2.00-2.49	F	33	852	35	775	805	841	900	923
24-29	2.00-2.49	Both	89	863	38	693	817	861	921	945
30-35	2.50-2.99	M	48	934	47	827	867	940	993	1077
30-35	2.50-2.99	F	43	898	37	813	841	894	971	975
30-35	2.50-2.99	Both	91	917	46	813	852	914	988	1077
36-47	3.00-3.99	M	48	995	51	901	913	996	1063	1143
36-47	3.00-3.99	F	31	981	38	905	912	982	1038	1045
36-47	3.00-3.99	Both	79	990	46	901	906	986	1058	1143
48-59	4.00-4.99	M	45	1046	51	869	981	1052	1129	1142
48-59	4.00-4.99	F	26	1054	30	999	1010	1058	1103	1110
48-59	4.00-4.99	Both	71	1049	44	869	984	1053	1112	1142
60-71	5.00-5.99	M	39	1128	51	1051	1056	1120	1207	1219
60-71	5.00-5.99	F	30	1104	43	1029	1037	1096	1169	1194
60-71	5.00-5.99	Both	69	1118	49	1029	1048	1107	1201	1219

Body Weight

Units: kg

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	56	13	1	8	11	13	15	17
24-29	2.00-2.49	F	33	12	1	10	10	12	15	16
24-29	2.00-2.49	Both	89	13	1	8	11	13	15	17
30-35	2.50-2.99	M	48	15	2	11	13	15	18	20
30-35	2.50-2.99	F	43	14	2	10	11	14	18	22
30-35	2.50-2.99	Both	91	14	2	10	12	14	18	22
36-47	3.00-3.99	M	48	16	2	13	14	16	19	21
36-47	3.00-3.99	F	31	15	2	13	13	15	18	19
36-47	3.00-3.99	Both	79	16	2	13	13	16	19	21
48-59	4.00-4.99	M	45	18	3	14	14	17	23	24
48-59	4.00-4.99	F	26	17	2	15	15	17	20	22
48-59	4.00-4.99	Both	71	18	2	14	14	17	23	24
60-71	5.00-5.99	M	39	21	3	17	17	20	26	29
60-71	5.00-5.99	F	30	19	3	14	16	19	24	25
60-71	5.00-5.99	Both	69	20	3	14	16	20	25	29

Sitting Height

Units: mm

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	56	526	26	420	484	524	565	572
24-29	2.00-2.49	F	33	508	26	454	467	507	547	557
24-29	2.00-2.49	Both	89	519	27	420	469	519	560	572
30-35	2.50-2.99	M	48	550	27	491	515	545	592	595
30-35	2.50-2.99	F	43	531	24	485	502	527	576	595
30-35	2.50-2.99	Both	91	541	27	485	502	536	589	595
36-47	3.00-3.99	M	48	571	21	515	536	571	601	614
36-47	3.00-3.99	F	31	557	24	511	517	556	590	602
36-47	3.00-3.99	Both	79	566	23	511	526	569	600	614
48-59	4.00-4.99	M	45	590	26	532	555	590	650	660
48-59	4.00-4.99	F	26	594	20	552	563	594	623	630
48-59	4.00-4.99	Both	71	591	24	532	557	592	627	660
60-71	5.00-5.99	M	39	620	47	380	592	617	665	679
60-71	5.00-5.99	F	30	612	26	563	573	609	652	654
60-71	5.00-5.99	Both	69	616	39	380	578	614	661	679

Shoulder (Acromion) Height, Standing

Units: mm

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	56	661	35	504	614	662	714	732
24-29	2.00-2.49	F	33	653	32	580	600	657	699	713
24-29	2.00-2.49	Both	89	658	34	504	610	657	709	732
30-35	2.50-2.99	M	48	713	41	623	647	716	767	838
30-35	2.50-2.99	F	43	690	36	605	624	686	760	769
30-35	2.50-2.99	Both	91	702	40	605	641	704	764	838
36-47	3.00-3.99	M	48	775	43	705	709	772	859	891
36-47	3.00-3.99	F	31	768	28	716	720	765	817	825
36-47	3.00-3.99	Both	79	772	38	705	715	768	826	891
48-59	4.00-4.99	M	45	826	41	753	758	828	894	898
48-59	4.00-4.99	F	26	839	28	795	799	835	881	913
48-59	4.00-4.99	Both	71	831	37	753	768	832	894	913
60-71	5.00-5.99	M	39	899	47	830	833	893	976	991
60-71	5.00-5.99	F	30	881	44	800	813	876	952	965
60-71	5.00-5.99	Both	69	891	46	800	826	888	964	991

Shoulder (Acromion) Height, Seated

Units: mm

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	56	330	13	278	313	329	350	355
24-29	2.00-2.49	F	33	323	11	303	306	323	339	344
24-29	2.00-2.49	Both	89	327	13	278	307	328	347	355
30-35	2.50-2.99	M	48	346	14	319	322	347	364	386
30-35	2.50-2.99	F	43	337	14	311	315	335	359	378
30-35	2.50-2.99	Both	91	342	14	311	320	343	362	386
36-47	3.00-3.99	M	48	368	14	339	348	365	395	412
36-47	3.00-3.99	F	31	361	10	328	350	360	375	381
36-47	3.00-3.99	Both	79	365	13	328	348	363	381	412
48-59	4.00-4.99	M	45	383	15	358	360	384	411	414
48-59	4.00-4.99	F	26	383	14	354	362	383	402	408
48-59	4.00-4.99	Both	71	383	14	354	360	384	407	414
60-71	5.00-5.99	M	39	409	17	376	384	408	438	444
60-71	5.00-5.99	F	30	399	15	372	379	398	422	429
60-71	5.00-5.99	Both	69	405	17	372	379	405	433	444

Shoulder (Bideltoid) Breadth

Units: mm

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	56	254	14	219	232	252	278	292
24-29	2.00-2.49	F	33	246	16	199	217	246	267	282
24-29	2.00-2.49	Both	89	251	15	199	227	251	278	292
30-35	2.50-2.99	M	48	265	10	240	245	264	282	285
30-35	2.50-2.99	F	43	259	14	230	241	257	288	299
30-35	2.50-2.99	Both	91	262	12	230	243	262	284	299
36-47	3.00-3.99	M	48	278	13	250	260	278	300	315
36-47	3.00-3.99	F	31	267	17	231	244	265	297	309
36-47	3.00-3.99	Both	79	274	15	231	251	273	300	315
48-59	4.00-4.99	M	45	289	18	262	265	286	322	335
48-59	4.00-4.99	F	26	282	15	255	258	281	307	314
48-59	4.00-4.99	Both	71	287	17	255	264	284	315	335
60-71	5.00-5.99	M	39	301	18	268	271	301	332	340
60-71	5.00-5.99	F	30	291	14	265	270	288	316	322
60-71	5.00-5.99	Both	69	297	17	265	269	295	325	340

Hip Breadth, Seated

Units: mm

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	56	213	12	187	198	211	236	255
24-29	2.00-2.49	F	33	203	14	163	177	206	221	232
24-29	2.00-2.49	Both	89	209	14	163	185	210	234	255
30-35	2.50-2.99	M	48	218	8	199	206	217	231	235
30-35	2.50-2.99	F	43	215	15	182	191	214	245	253
30-35	2.50-2.99	Both	91	217	12	182	195	217	234	253
36-47	3.00-3.99	M	48	227	12	201	210	224	250	259
36-47	3.00-3.99	F	31	217	16	194	198	215	250	260
36-47	3.00-3.99	Both	79	223	15	194	201	221	250	260
48-59	4.00-4.99	M	45	235	16	210	215	234	264	276
48-59	4.00-4.99	F	26	231	15	206	210	230	255	267
48-59	4.00-4.99	Both	71	234	16	206	212	232	261	276
60-71	5.00-5.99	M	39	244	17	214	222	243	269	297
60-71	5.00-5.99	F	30	235	15	213	216	231	262	268
60-71	5.00-5.99	Both	69	240	16	213	216	239	268	297

Elbow Height, Standing

Units: mm

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	56	557	27	439	521	555	597	620
24-29	2.00-2.49	F	33	547	23	496	512	546	583	585
24-29	2.00-2.49	Both	89	553	26	439	517	554	591	620
30-35	2.50-2.99	M	48	597	31	519	546	598	635	690
30-35	2.50-2.99	F	43	576	27	514	528	571	634	638
30-35	2.50-2.99	Both	91	587	31	514	540	588	636	690
36-47	3.00-3.99	M	48	644	34	576	591	642	700	742
36-47	3.00-3.99	F	31	634	22	591	601	627	667	681
36-47	3.00-3.99	Both	79	640	30	576	591	640	682	742
48-59	4.00-4.99	M	45	683	32	622	639	688	733	743
48-59	4.00-4.99	F	26	688	18	654	663	689	714	719
48-59	4.00-4.99	Both	71	685	27	622	639	688	723	743
60-71	5.00-5.99	M	39	739	39	672	689	733	801	825
60-71	5.00-5.99	F	30	719	31	657	671	719	764	773
60-71	5.00-5.99	Both	69	731	37	657	675	723	786	825

Elbow Height, Seated

Units: mm

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	56	227	9	204	215	224	242	244
24-29	2.00-2.49	F	33	217	13	189	200	219	237	248
24-29	2.00-2.49	Both	89	223	11	189	203	223	243	248
30-35	2.50-2.99	M	48	230	10	202	217	228	251	253
30-35	2.50-2.99	F	43	223	9	205	209	222	242	253
30-35	2.50-2.99	Both	91	227	10	202	212	226	247	253
36-47	3.00-3.99	M	48	237	8	216	228	234	249	254
36-47	3.00-3.99	F	31	228	14	201	209	228	257	261
36-47	3.00-3.99	Both	79	233	12	201	214	233	249	261
48-59	4.00-4.99	M	45	240	8	218	228	239	253	258
48-59	4.00-4.99	F	26	233	18	202	210	232	268	274
48-59	4.00-4.99	Both	71	237	13	202	214	238	253	274
60-71	5.00-5.99	M	39	250	13	228	233	248	271	274
60-71	5.00-5.99	F	30	238	16	197	219	236	263	282
60-71	5.00-5.99	Both	69	245	15	197	223	242	271	282

Elbow-Fingertip Length

Units: mm

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	56	203	13	160	183	204	225	232
24-29	2.00-2.49	F	33	205	14	174	182	209	219	250
24-29	2.00-2.49	Both	89	204	14	160	182	204	224	250
30-35	2.50-2.99	M	48	220	14	197	199	221	243	258
30-35	2.50-2.99	F	43	214	13	183	190	213	234	244
30-35	2.50-2.99	Both	91	217	14	183	198	218	238	258
36-47	3.00-3.99	M	48	240	15	202	216	238	267	284
36-47	3.00-3.99	F	31	239	12	213	221	237	258	261
36-47	3.00-3.99	Both	79	239	14	202	217	237	260	284
48-59	4.00-4.99	M	45	256	17	216	232	254	283	288
48-59	4.00-4.99	F	26	258	12	237	245	258	281	285
48-59	4.00-4.99	Both	71	257	15	216	233	256	283	288
60-71	5.00-5.99	M	39	275	19	235	253	273	301	326
60-71	5.00-5.99	F	30	269	19	243	245	265	302	305
60-71	5.00-5.99	Both	69	272	19	235	246	271	302	326

Elbow-Grip Length

Units: mm

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	56	152	11	117	133	152	170	175
24-29	2.00-2.49	F	33	154	13	125	135	156	166	194
24-29	2.00-2.49	Both	89	153	12	117	133	153	169	194
30-35	2.50-2.99	M	48	166	11	146	148	166	185	197
30-35	2.50-2.99	F	43	160	11	129	141	160	176	186
30-35	2.50-2.99	Both	91	163	11	129	146	163	181	197
36-47	3.00-3.99	M	48	182	13	150	162	180	204	218
36-47	3.00-3.99	F	31	182	11	158	163	179	197	199
36-47	3.00-3.99	Both	79	182	12	150	161	180	199	218
48-59	4.00-4.99	M	45	195	15	159	176	192	219	222
48-59	4.00-4.99	F	26	197	12	174	184	197	218	220
48-59	4.00-4.99	Both	71	196	14	159	176	195	219	222
60-71	5.00-5.99	M	39	210	16	174	191	209	231	253
60-71	5.00-5.99	F	30	205	17	180	184	203	233	239
60-71	5.00-5.99	Both	69	208	16	174	186	206	233	253

Shoulder-Elbow (Acromion-Radiale) Length

Units: mm

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	56	148	23	87	122	144	194	198
24-29	2.00-2.49	F	33	145	27	93	108	143	190	214
24-29	2.00-2.49	Both	89	147	25	87	116	143	194	214
30-35	2.50-2.99	M	48	156	21	109	119	157	193	201
30-35	2.50-2.99	F	43	155	26	96	123	151	200	227
30-35	2.50-2.99	Both	91	155	23	96	119	155	196	227
36-47	3.00-3.99	M	48	168	31	105	120	171	216	254
36-47	3.00-3.99	F	31	173	31	130	132	168	239	254
36-47	3.00-3.99	Both	79	170	31	105	129	169	222	254
48-59	4.00-4.99	M	45	184	31	125	134	184	226	297
48-59	4.00-4.99	F	26	205	45	134	153	200	278	341
48-59	4.00-4.99	Both	71	191	38	125	138	186	258	341
60-71	5.00-5.99	M	39	206	32	150	159	207	252	290
60-71	5.00-5.99	F	30	206	49	133	148	195	312	315
60-71	5.00-5.99	Both	69	206	40	133	153	203	292	315

Elbow-Wrist (Radiale-Stylion) Length

Units: mm

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	56	132	6	107	125	131	141	146
24-29	2.00-2.49	F	33	131	6	119	122	131	138	144
24-29	2.00-2.49	Both	89	131	6	107	124	131	141	146
30-35	2.50-2.99	M	48	141	7	124	130	141	150	160
30-35	2.50-2.99	F	43	136	6	123	126	135	147	153
30-35	2.50-2.99	Both	91	138	7	123	128	139	149	160
36-47	3.00-3.99	M	48	150	7	136	140	150	162	171
36-47	3.00-3.99	F	31	148	5	139	140	147	156	161
36-47	3.00-3.99	Both	79	149	7	136	140	149	159	171
48-59	4.00-4.99	M	45	159	7	147	148	160	169	170
48-59	4.00-4.99	F	26	160	5	151	152	160	167	168
48-59	4.00-4.99	Both	71	159	6	147	148	160	169	170
60-71	5.00-5.99	M	39	171	9	158	160	172	187	189
60-71	5.00-5.99	F	30	167	8	154	155	166	180	181
60-71	5.00-5.99	Both	69	169	9	154	158	169	183	189

Hand Length

Units: mm

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	56	103	5	87	98	103	110	117
24-29	2.00-2.49	F	33	102	4	94	95	101	108	112
24-29	2.00-2.49	Both	89	103	4	87	96	102	110	117
30-35	2.50-2.99	M	48	109	5	96	101	109	118	123
30-35	2.50-2.99	F	43	106	5	98	99	106	116	117
30-35	2.50-2.99	Both	91	108	5	96	99	108	117	123
36-47	3.00-3.99	M	48	116	6	104	107	116	128	131
36-47	3.00-3.99	F	31	114	4	108	110	114	121	124
36-47	3.00-3.99	Both	79	115	5	104	108	115	124	131
48-59	4.00-4.99	M	45	123	6	110	114	123	131	132
48-59	4.00-4.99	F	26	122	3	117	117	122	127	130
48-59	4.00-4.99	Both	71	122	5	110	115	122	130	132
60-71	5.00-5.99	M	39	130	7	119	121	128	143	147
60-71	5.00-5.99	F	30	127	6	117	119	126	137	139
60-71	5.00-5.99	Both	69	129	7	117	119	128	141	147

Hand Breadth

Units: mm

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	56	50	2	41	47	50	54	55
24-29	2.00-2.49	F	33	48	3	43	45	48	53	54
24-29	2.00-2.49	Both	89	49	3	41	46	49	54	55
30-35	2.50-2.99	M	48	52	3	45	49	52	56	59
30-35	2.50-2.99	F	43	51	3	45	46	50	56	59
30-35	2.50-2.99	Both	91	52	3	45	47	52	57	59
36-47	3.00-3.99	M	48	55	3	49	50	55	60	64
36-47	3.00-3.99	F	31	54	2	51	51	54	58	60
36-47	3.00-3.99	Both	79	55	3	49	50	54	60	64
48-59	4.00-4.99	M	45	59	3	53	54	59	62	65
48-59	4.00-4.99	F	26	59	3	53	55	59	64	69
48-59	4.00-4.99	Both	71	59	3	53	54	59	63	69
60-71	5.00-5.99	M	39	63	4	57	57	62	69	71
60-71	5.00-5.99	F	30	61	3	54	57	61	67	68
60-71	5.00-5.99	Both	69	62	4	54	57	62	69	71

Hand Breadth with Thumb

Units: mm

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	56	62	2	54	60	62	66	68
24-29	2.00-2.49	F	33	61	2	58	59	62	64	65
24-29	2.00-2.49	Both	89	62	2	54	59	62	65	68
30-35	2.50-2.99	M	48	65	2	59	62	65	68	72
30-35	2.50-2.99	F	43	64	2	59	60	63	68	70
30-35	2.50-2.99	Both	91	64	2	59	60	64	68	72
36-47	3.00-3.99	M	48	69	3	65	66	69	74	76
36-47	3.00-3.99	F	31	67	2	64	64	67	70	72
36-47	3.00-3.99	Both	79	68	2	64	65	68	72	76
48-59	4.00-4.99	M	45	71	3	67	67	72	76	77
48-59	4.00-4.99	F	26	72	2	68	68	72	75	76
48-59	4.00-4.99	Both	71	71	3	67	68	72	76	77
60-71	5.00-5.99	M	39	76	3	71	71	75	80	82
60-71	5.00-5.99	F	30	74	3	69	70	74	79	79
60-71	5.00-5.99	Both	69	75	3	69	71	75	80	82

Buttock-Knee Length

Units: mm

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	56	282	28	216	238	277	332	343
24-29	2.00-2.49	F	33	270	29	212	219	276	313	329
24-29	2.00-2.49	Both	89	277	28	212	223	277	327	343
30-35	2.50-2.99	M	48	295	28	194	259	296	339	373
30-35	2.50-2.99	F	43	282	28	221	241	279	332	341
30-35	2.50-2.99	Both	91	289	28	194	245	292	334	373
36-47	3.00-3.99	M	48	312	29	235	266	311	350	405
36-47	3.00-3.99	F	31	310	25	257	260	313	344	355
36-47	3.00-3.99	Both	79	311	27	235	261	312	349	405
48-59	4.00-4.99	M	45	336	28	277	298	328	385	407
48-59	4.00-4.99	F	26	340	39	281	287	342	416	454
48-59	4.00-4.99	Both	71	338	32	277	289	336	391	454
60-71	5.00-5.99	M	39	363	41	274	303	357	429	447
60-71	5.00-5.99	F	30	357	30	292	311	354	410	414
60-71	5.00-5.99	Both	69	361	36	274	300	357	416	447

Knee Height

Units: mm

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	56	244	14	185	226	242	266	273
24-29	2.00-2.49	F	33	243	14	213	218	245	264	270
24-29	2.00-2.49	Both	89	243	14	185	223	243	265	273
30-35	2.50-2.99	M	48	264	17	229	238	265	291	313
30-35	2.50-2.99	F	43	257	15	224	231	255	285	292
30-35	2.50-2.99	Both	91	261	16	224	236	262	287	313
36-47	3.00-3.99	M	48	287	18	244	262	286	324	334
36-47	3.00-3.99	F	31	287	12	262	267	287	309	316
36-47	3.00-3.99	Both	79	287	16	244	262	286	314	334
48-59	4.00-4.99	M	45	309	17	277	281	307	335	343
48-59	4.00-4.99	F	26	315	14	292	297	313	337	341
48-59	4.00-4.99	Both	71	311	16	277	283	312	337	343
60-71	5.00-5.99	M	39	335	20	303	307	334	366	383
60-71	5.00-5.99	F	30	330	22	293	300	326	366	368
60-71	5.00-5.99	Both	69	333	21	293	304	332	366	383

Ankle (Lateral Malleolus) Height

Units: mm

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	56	48	2	38	45	48	52	54
24-29	2.00-2.49	F	33	47	2	43	44	47	50	51
24-29	2.00-2.49	Both	89	48	2	38	45	48	51	54
30-35	2.50-2.99	M	48	52	3	45	47	52	55	60
30-35	2.50-2.99	F	43	50	2	45	46	49	55	55
30-35	2.50-2.99	Both	91	51	3	45	47	51	55	60
36-47	3.00-3.99	M	48	56	3	50	51	55	60	64
36-47	3.00-3.99	F	31	55	2	51	52	54	58	59
36-47	3.00-3.99	Both	79	55	3	50	51	55	59	64
48-59	4.00-4.99	M	45	59	3	54	55	59	63	64
48-59	4.00-4.99	F	26	59	2	56	57	59	62	62
48-59	4.00-4.99	Both	71	59	2	54	55	59	62	64
60-71	5.00-5.99	M	39	64	3	58	59	63	69	71
60-71	5.00-5.99	F	30	62	3	57	58	62	66	67
60-71	5.00-5.99	Both	69	63	3	57	58	62	68	71

Foot Length

Units: mm

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	56	140	7	111	130	140	150	157
24-29	2.00-2.49	F	33	137	6	125	127	138	146	150
24-29	2.00-2.49	Both	89	139	7	111	128	139	148	157
30-35	2.50-2.99	M	48	149	8	131	137	150	158	172
30-35	2.50-2.99	F	43	144	8	129	132	142	159	165
30-35	2.50-2.99	Both	91	147	8	129	135	147	159	172
36-47	3.00-3.99	M	48	160	9	144	148	160	179	185
36-47	3.00-3.99	F	31	158	6	143	149	157	167	172
36-47	3.00-3.99	Both	79	159	8	143	148	159	173	185
48-59	4.00-4.99	M	45	170	9	154	156	172	183	186
48-59	4.00-4.99	F	26	172	7	161	162	172	184	188
48-59	4.00-4.99	Both	71	171	8	154	157	172	184	188
60-71	5.00-5.99	M	39	185	11	170	171	183	201	208
60-71	5.00-5.99	F	30	179	9	164	168	179	193	196
60-71	5.00-5.99	Both	69	182	10	164	168	181	200	208

Foot Breadth

Units: mm

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	56	65	3	56	62	65	70	73
24-29	2.00-2.49	F	33	64	3	57	60	64	67	68
24-29	2.00-2.49	Both	89	65	3	56	61	65	69	73
30-35	2.50-2.99	M	48	69	3	59	64	69	72	76
30-35	2.50-2.99	F	43	66	3	59	62	66	73	74
30-35	2.50-2.99	Both	91	68	3	59	62	68	73	76
36-47	3.00-3.99	M	48	72	4	64	65	72	81	82
36-47	3.00-3.99	F	31	71	3	67	68	71	77	77
36-47	3.00-3.99	Both	79	72	4	64	67	71	78	82
48-59	4.00-4.99	M	45	76	3	70	71	76	81	82
48-59	4.00-4.99	F	26	76	3	69	72	76	80	82
48-59	4.00-4.99	Both	71	76	3	69	71	76	81	82
60-71	5.00-5.99	M	39	82	5	75	76	80	90	91
60-71	5.00-5.99	F	30	78	4	69	73	79	84	89
60-71	5.00-5.99	Both	69	80	5	69	74	80	88	91

APPENDIX D: Summary Statistics for Force Exertion

This appendix contains tables of summary statistics for force exertion across the 36 task conditions listed in the body of the report. Within each trial, the highest value of a one-second moving average of the on-axis force was computed. The largest value across the trials in each condition for each subject was used to compute the statistics in this appendix. The N values in each table reflect the number of subjects for whom valid data were available.

Note that the child photos in this appendix were staged with a child for whom we obtained a photo release. These photos were not taken during data collection. The environment was modified to improve the clarity of the photos, including by using a backdrop. During data collection two investigators and the child's caregiver were always present.

All units are Newtons except that the TurnKnob_40mm_Elbow_CW results are reported in Newton-meters.

The scatter plots include an approximating curve for each gender created by local polynomial regression fitting (also known as local estimation smoothing, or loess). The curve is constructed by generating an approximating point at each value of the independent variable. Each of these points on the curve is created by fitting a quadratic function to the points near the desired point, weighting points closer to the point of interest higher than those farther away. The complete curve is obtained by a line passing through these individual points. The algorithm uses the geom_smooth() function in the ggplot2 library in R version 4.3.2, which is based on the loess() function in R. Default values for loess() were used, which include quadratic local fitting. When a plot has relatively few data points, and at the ends, the curve is a less reliable approximation of the trend in the data. These curves are intended to show qualitative trends and should not be taken as representing the true mean value at any point in the curve.

The box plots were created using the geom_boxplot() function using the ggplot2 library in R 4.3.2. Boxplots are a non-parametric way to represent the distribution of a dataset. The line across the center of the box shows the median value within the group. The lower and upper ends of the box correspond to the first and third quartiles (the 25th and 75th percentiles), i.e., the interquartile range (IQR). The upper whisker (line) extends from the box to the largest value no further than 1.5 * IQR from the box. The lower whisker extends from the box to the smallest value at most 1.5 * IQR of the box. Data beyond the end of the whiskers are called "outlying" points and are plotted individually.

1H_Thigh_Pull

Description: One-hand maximal pull exertion at mid-thigh height

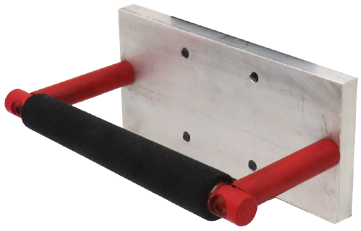
Configuration: 1H_Bar_Stand

Position: The vertical position of the 1H bar was set to 41% of measured stature, approximately mid-thigh height.

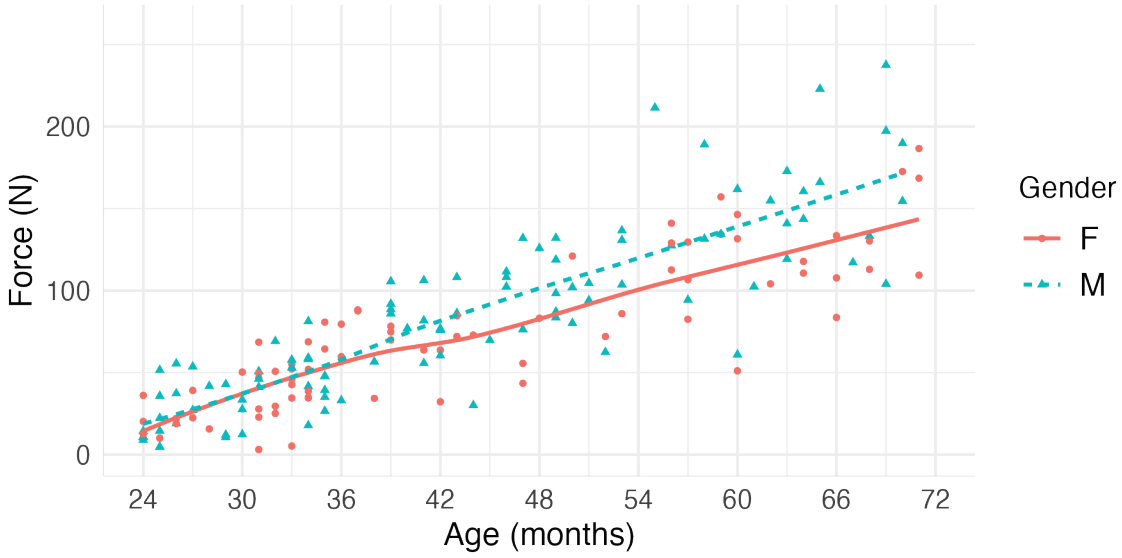
Posture: Standing

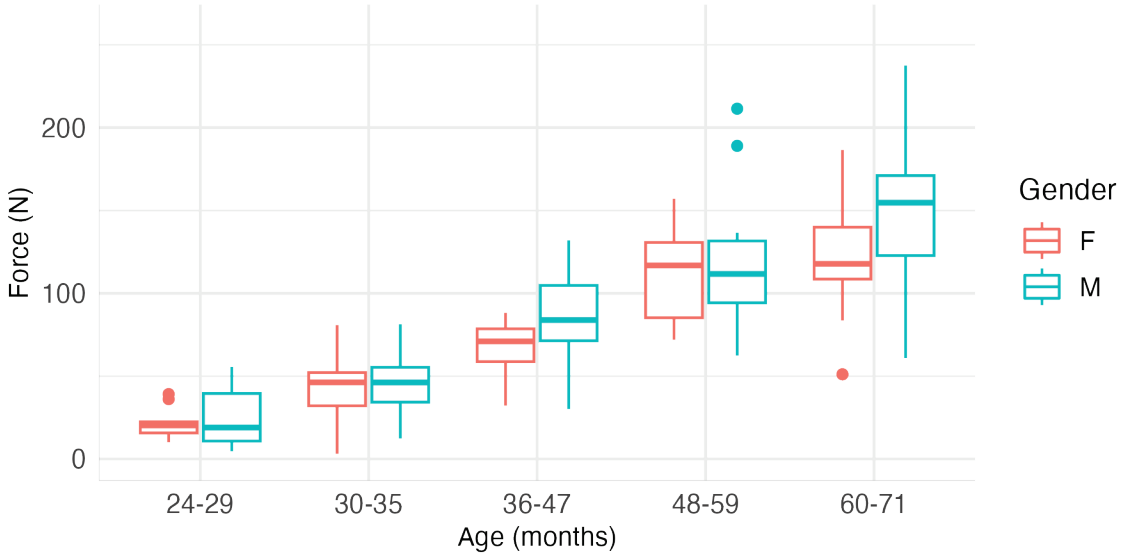
Interface: 1H_Bar_Horz

Units: Newton



1H_Thigh_Pull





1H_Thigh_Pull (N)

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	19	25.2	17.4	4.6	4.8	19.0	53.8	55.5
24-29	2.00-2.49	F	9	21.9	9.8	10.1	11.1	20.2	37.9	39.1
24-29	2.00-2.49	Both	28	24.1	15.3	4.6	6.2	19.6	52.9	55.5
30-35	2.50-2.99	M	19	44.5	17.1	12.3	17.3	46.2	70.4	81.3
30-35	2.50-2.99	F	23	42.8	19.2	3.2	7.0	46.2	68.7	80.8
30-35	2.50-2.99	Both	42	43.6	18.1	3.2	12.6	46.2	69.1	81.3
36-47	3.00-3.99	M	22	82.7	25.5	30.1	34.2	83.9	111.3	131.9
36-47	3.00-3.99	F	16	66.3	17.6	32.2	33.8	71.0	87.8	88.2
36-47	3.00-3.99	Both	38	75.8	23.7	30.1	32.9	76.5	108.6	131.9
48-59	4.00-4.99	M	20	117.4	35.5	62.5	79.3	111.7	190.1	211.4
48-59	4.00-4.99	F	12	112.9	27.1	72.0	77.8	116.8	148.3	157.1
48-59	4.00-4.99	Both	32	115.7	32.2	62.5	76.5	115.7	171.5	211.4
60-71	5.00-5.99	M	18	152.2	43.7	61.0	96.2	154.7	225.1	237.5
60-71	5.00-5.99	F	15	124.4	34.9	51.1	73.9	117.8	176.8	186.6
60-71	5.00-5.99	Both	33	139.6	41.8	51.1	74.5	133.5	207.5	237.5

1H_Thigh_Push

Description: One-hand maximal push exertion at mid-thigh height

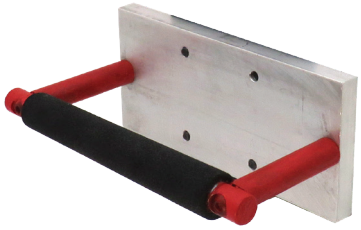
Configuration: 1H_Bar_Stand

Position: The vertical position of the 1H bar was set to 41% of measured stature, approximately mid-thigh height.

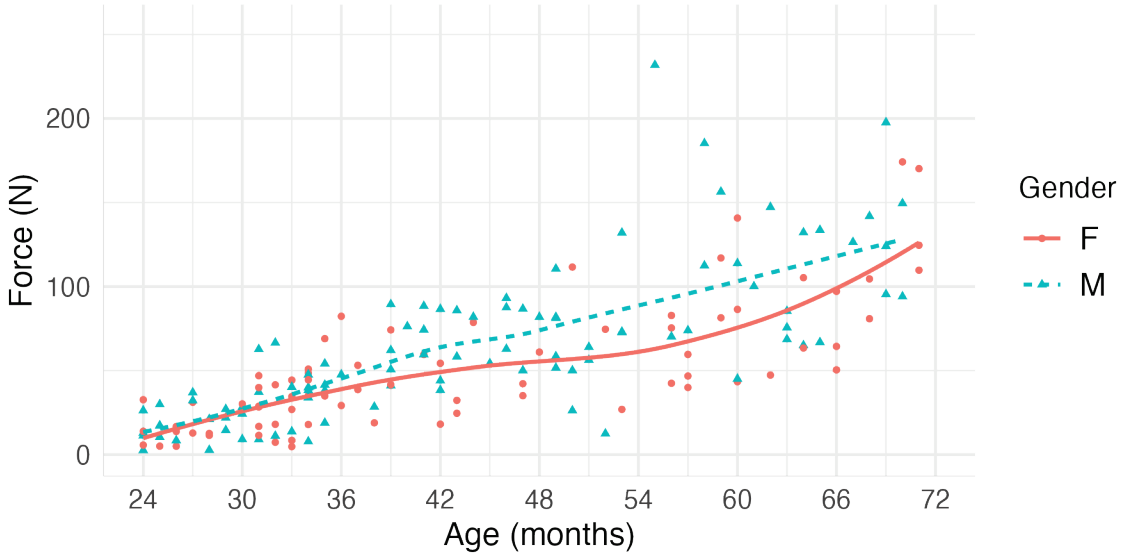
Posture: Standing

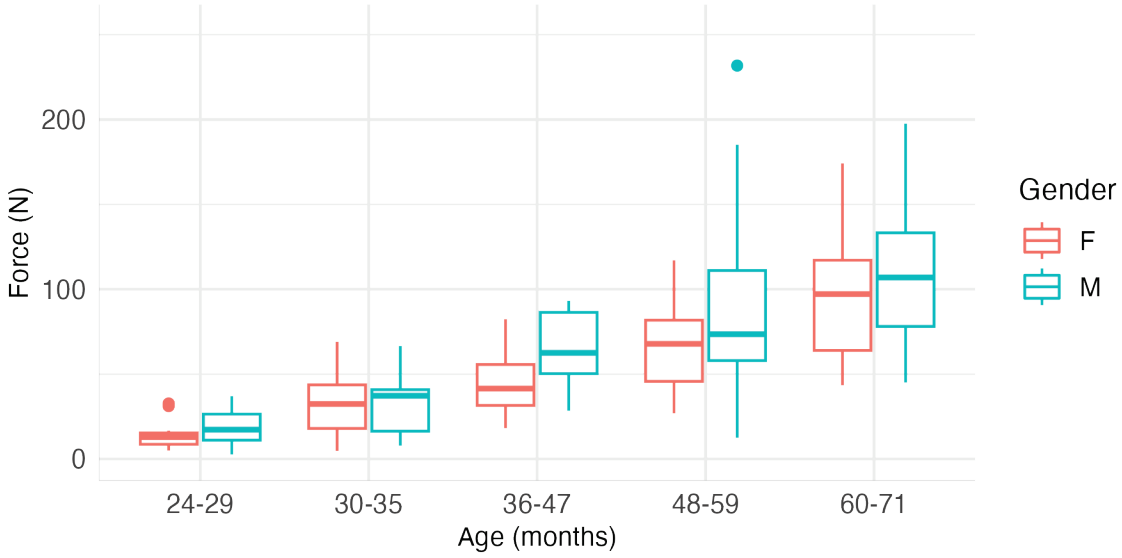
Interface: 1H_Bar_Horz

Units: Newton



1H_Thigh_Push





1H_Thigh_Push (N)

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	16	18.3	10.3	2.6	2.7	17.2	33.4	37.0
24-29	2.00-2.49	F	11	14.6	9.4	5.0	5.0	12.9	31.9	32.7
24-29	2.00-2.49	Both	27	16.8	9.9	2.6	3.4	13.9	32.5	37.0
30-35	2.50-2.99	M	19	32.8	18.0	7.8	8.9	37.2	63.1	66.6
30-35	2.50-2.99	F	22	31.3	16.5	4.8	7.4	32.4	50.8	69.0
30-35	2.50-2.99	Both	41	32.0	17.0	4.8	7.8	34.6	62.7	69.0
36-47	3.00-3.99	M	22	65.8	19.9	28.5	38.5	62.5	89.4	93.2
36-47	3.00-3.99	F	16	45.3	20.2	18.1	18.7	41.5	79.6	82.3
36-47	3.00-3.99	Both	38	57.2	22.3	18.1	23.8	54.3	88.6	93.2
48-59	4.00-4.99	M	20	89.1	53.1	12.5	25.6	73.5	187.6	231.8
48-59	4.00-4.99	F	12	68.3	27.8	26.9	34.1	67.8	114.0	117.0
48-59	4.00-4.99	Both	32	81.3	45.9	12.5	26.6	73.5	169.4	231.8
60-71	5.00-5.99	M	18	109.0	38.6	45.1	62.0	106.9	156.7	197.6
60-71	5.00-5.99	F	15	97.5	41.7	43.4	46.1	97.2	171.4	174.2
60-71	5.00-5.99	Both	33	103.8	39.8	43.4	46.4	100.1	171.8	197.6

1H_Thigh_Up

Description: One-hand maximal upward exertion at mid-thigh height

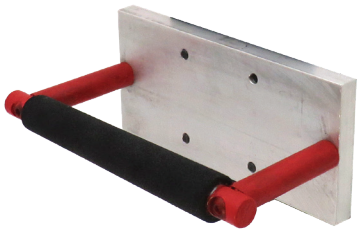
Configuration: 1H_Bar_Stand

Position: The vertical position of the 1H bar was set to 41% of measured stature, approximately mid-thigh height.

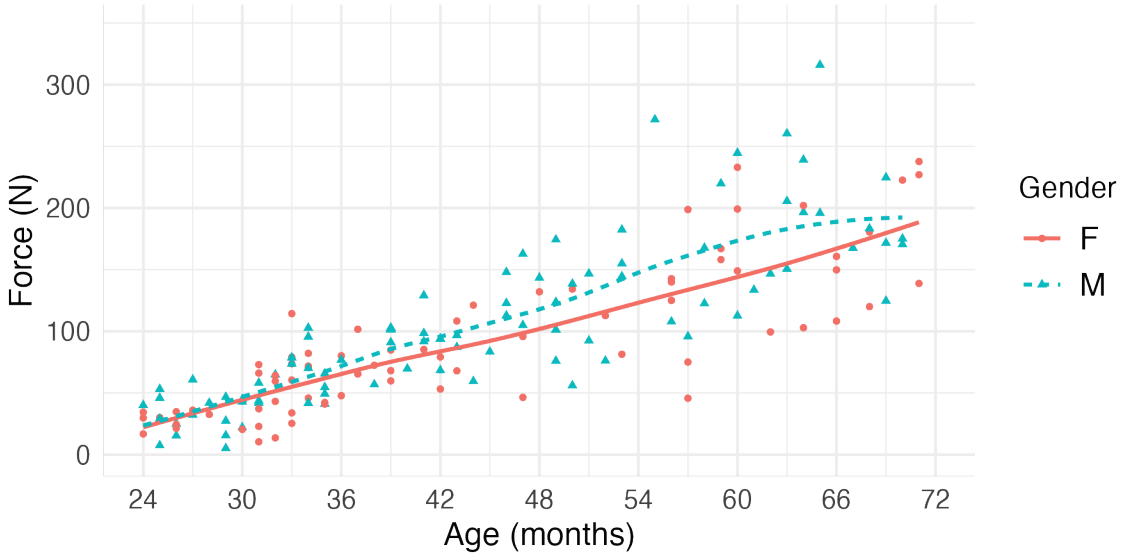
Posture: Standing

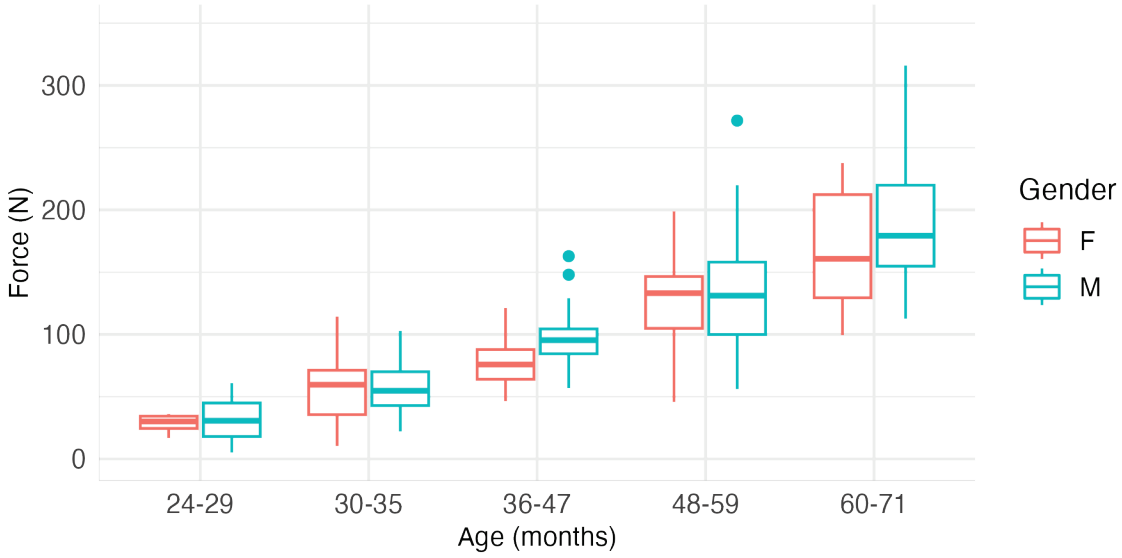
Interface: 1H_Bar_Horz

Units: Newton



1H_Thigh_Up


Force (N)
300
200
100
0
24
30
36
42
48
54
60
66
72
Age (months)
Gender
F
M


Force (N)
300
200
100
0
24-29
30-35
36-47
48-59
60-71
Age (months)
Gender
F
M

1H_Thigh_Up (N)

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	14	31.9	17.1	5.2	6.7	30.7	55.9	60.8
24-29	2.00-2.49	F	9	28.9	6.7	16.8	18.6	30.1	35.6	36.1
24-29	2.00-2.49	Both	23	30.7	13.8	5.2	8.3	30.1	52.5	60.8
30-35	2.50-2.99	M	17	58.3	21.1	22.1	37.3	54.7	97.0	102.8
30-35	2.50-2.99	F	23	53.1	25.8	10.4	14.3	59.6	81.8	114.4
30-35	2.50-2.99	Both	40	55.3	23.8	10.4	20.2	56.4	95.9	114.4
36-47	3.00-3.99	M	22	97.9	26.1	56.9	60.0	95.4	147.0	162.8
36-47	3.00-3.99	F	16	77.4	21.6	46.4	47.5	75.8	111.5	121.2
36-47	3.00-3.99	Both	38	89.3	26.1	46.4	52.4	89.1	131.9	162.8
48-59	4.00-4.99	M	20	136.0	51.4	56.1	75.0	131.1	222.4	271.7
48-59	4.00-4.99	F	12	126.1	42.4	45.8	61.9	133.2	181.3	198.7
48-59	4.00-4.99	Both	32	132.3	47.8	45.8	66.5	133.2	208.2	271.7
60-71	5.00-5.99	M	18	189.9	52.1	112.7	122.9	179.3	268.7	315.9
60-71	5.00-5.99	F	15	168.7	49.4	99.5	101.9	160.7	234.4	237.7
60-71	5.00-5.99	Both	33	180.3	51.2	99.5	106.2	175.1	250.9	315.9

1H_Elbow_Pull

Description: One-hand maximal pull exertion at elbow height

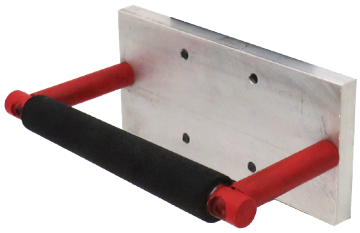
Configuration: 1H_Bar_Stand

Position: The vertical position of the 1H bar was set to 63% of measured stature, approximately elbow height.

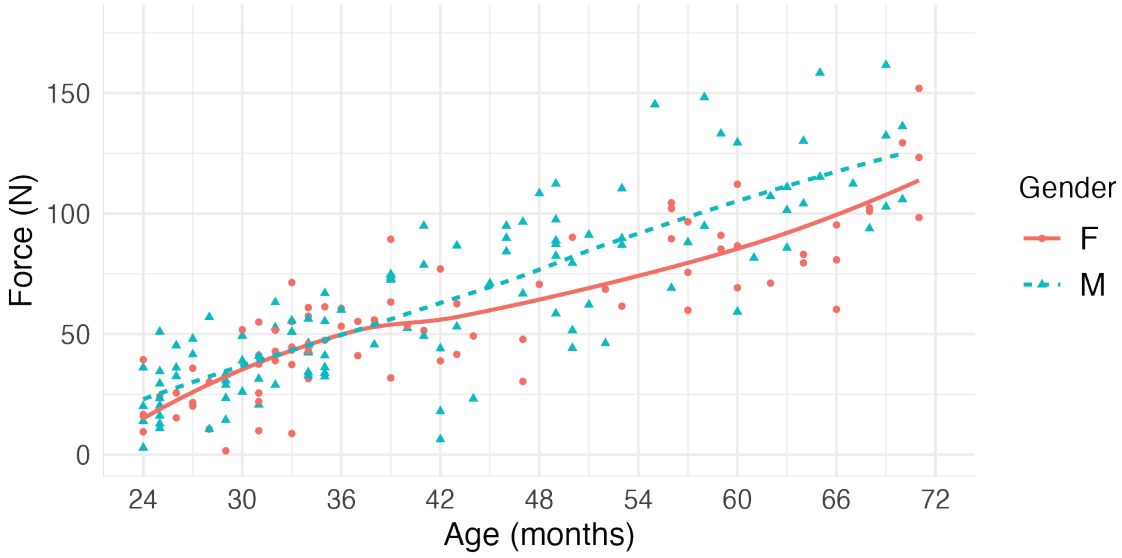
Posture: Standing

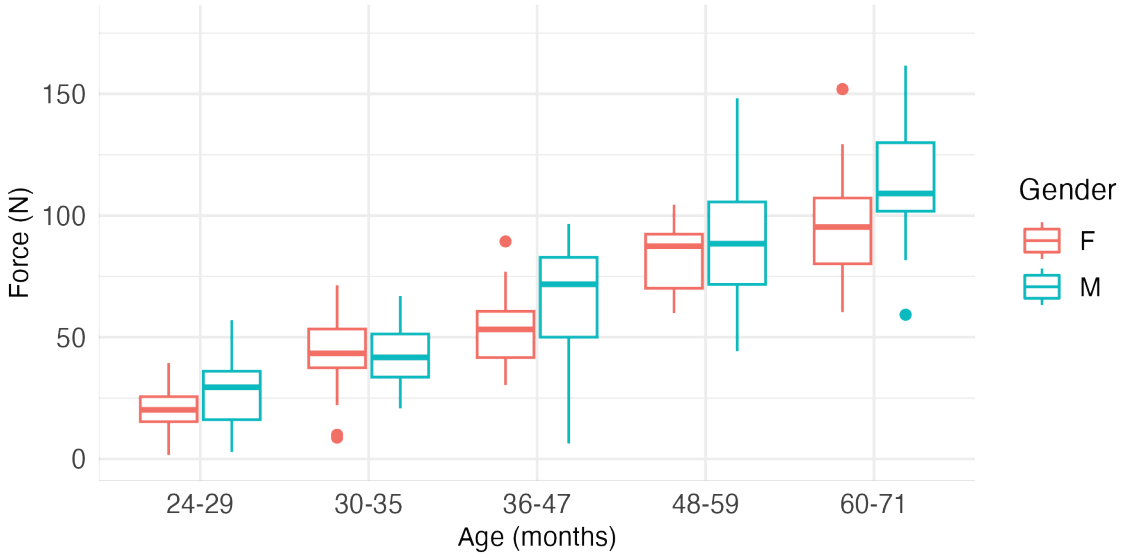
Interface: 1H_Bar_Horz

Units: Newton



1H_Elbow_Pull





1H_Elbow_Pull (N)

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	25	28.3	13.9	2.8	10.6	29.4	50.4	57.0
24-29	2.00-2.49	F	13	20.5	10.7	1.6	6.3	20.2	37.3	39.4
24-29	2.00-2.49	Both	38	25.6	13.3	1.6	8.5	23.8	48.5	57.0
30-35	2.50-2.99	M	24	42.7	11.9	20.7	26.5	41.7	62.2	67.0
30-35	2.50-2.99	F	23	42.8	15.6	8.8	11.1	43.4	61.3	71.4
30-35	2.50-2.99	Both	47	42.8	13.7	8.8	21.1	43.1	62.6	71.4
36-47	3.00-3.99	M	22	64.1	25.4	6.3	18.2	71.8	94.9	96.6
36-47	3.00-3.99	F	17	53.1	15.1	30.4	31.5	53.2	79.5	89.4
36-47	3.00-3.99	Both	39	59.3	22.0	6.3	22.7	55.9	94.9	96.6
48-59	4.00-4.99	M	22	89.8	28.9	44.2	46.4	88.4	144.7	148.2
48-59	4.00-4.99	F	12	83.0	15.3	59.9	60.8	87.4	103.2	104.5
48-59	4.00-4.99	Both	34	87.4	24.9	44.2	49.7	88.4	137.4	148.2
60-71	5.00-5.99	M	18	112.7	25.8	59.3	78.3	109.1	158.9	161.6
60-71	5.00-5.99	F	15	96.3	24.9	60.3	66.6	95.3	136.1	152.0
60-71	5.00-5.99	Both	33	105.2	26.3	59.3	65.7	102.9	154.5	161.6

1H_Elbow_Push

Description: One-hand maximal push exertion at elbow height

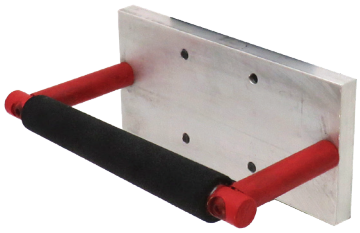
Configuration: 1H_Bar_Stand

Position: The vertical position of the 1Hbar was set to 63% of measured stature, approximately elbow height.

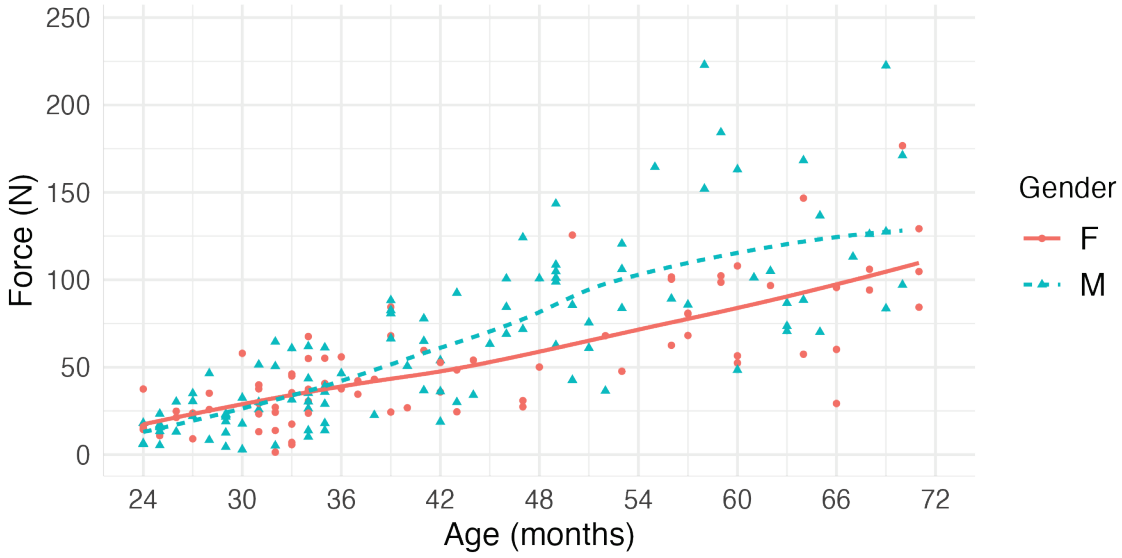
Posture: Standing

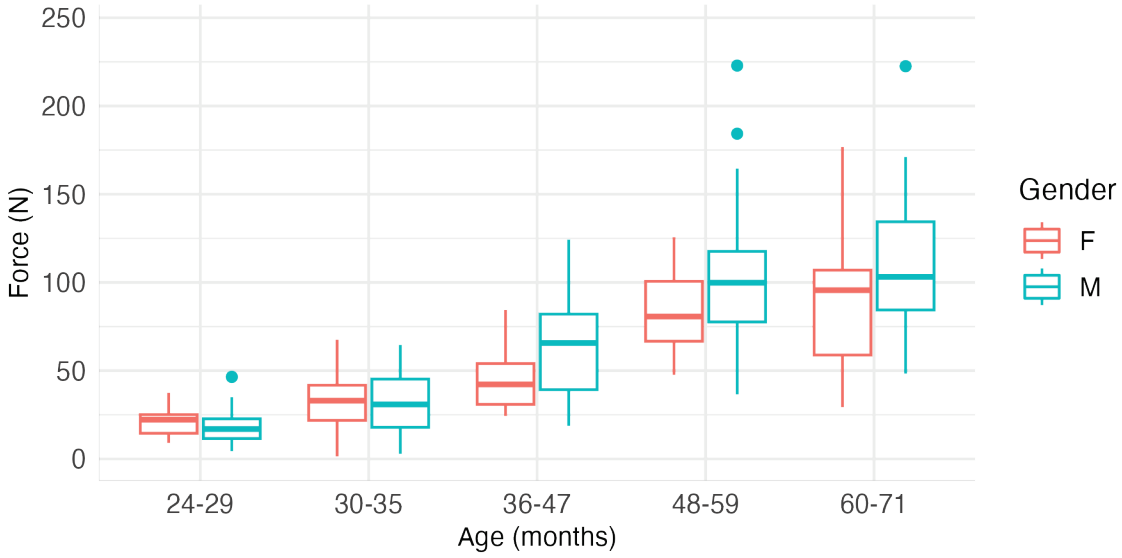
Interface: 1H_Bar_Horz

Units: Newton



1H_Elbow_Push



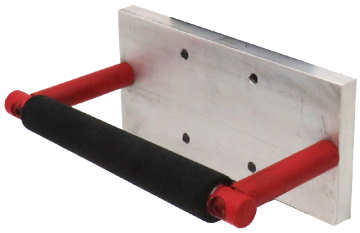


1H_Elbow_Push (N)

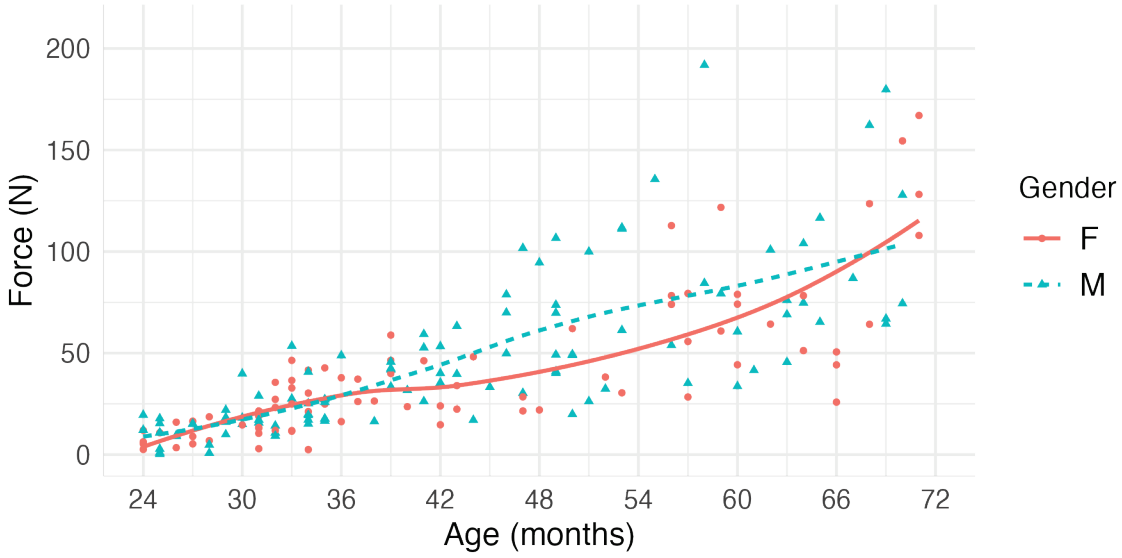
Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	24	18.1	10.3	4.4	5.4	16.9	34.3	46.5
24-29	2.00-2.49	F	12	21.4	8.9	9.1	10.0	22.2	36.2	37.5
24-29	2.00-2.49	Both	36	19.2	9.9	4.4	5.8	17.7	35.7	46.5
30-35	2.50-2.99	M	24	33.0	18.3	2.9	5.9	30.9	61.8	64.6
30-35	2.50-2.99	F	24	32.3	17.5	1.4	5.9	33.0	57.5	67.6
30-35	2.50-2.99	Both	48	32.6	17.7	1.4	5.4	31.0	61.7	67.6
36-47	3.00-3.99	M	22	63.5	27.3	18.8	23.0	65.7	100.3	124.2
36-47	3.00-3.99	F	17	44.2	16.8	24.3	24.5	42.2	71.3	84.4
36-47	3.00-3.99	Both	39	55.0	25.0	18.8	24.2	52.7	93.3	124.2
48-59	4.00-4.99	M	22	103.3	46.9	36.5	42.6	99.8	183.3	222.9
48-59	4.00-4.99	F	12	82.2	23.9	47.7	49.0	80.7	112.8	125.6
48-59	4.00-4.99	Both	34	95.9	41.2	36.5	42.6	93.9	171.4	222.9
60-71	5.00-5.99	M	18	114.1	44.6	48.4	66.9	103.2	178.8	222.5
60-71	5.00-5.99	F	15	93.2	38.9	29.3	45.5	95.6	155.7	176.7
60-71	5.00-5.99	Both	33	104.6	42.8	29.3	50.8	97.1	173.4	222.5

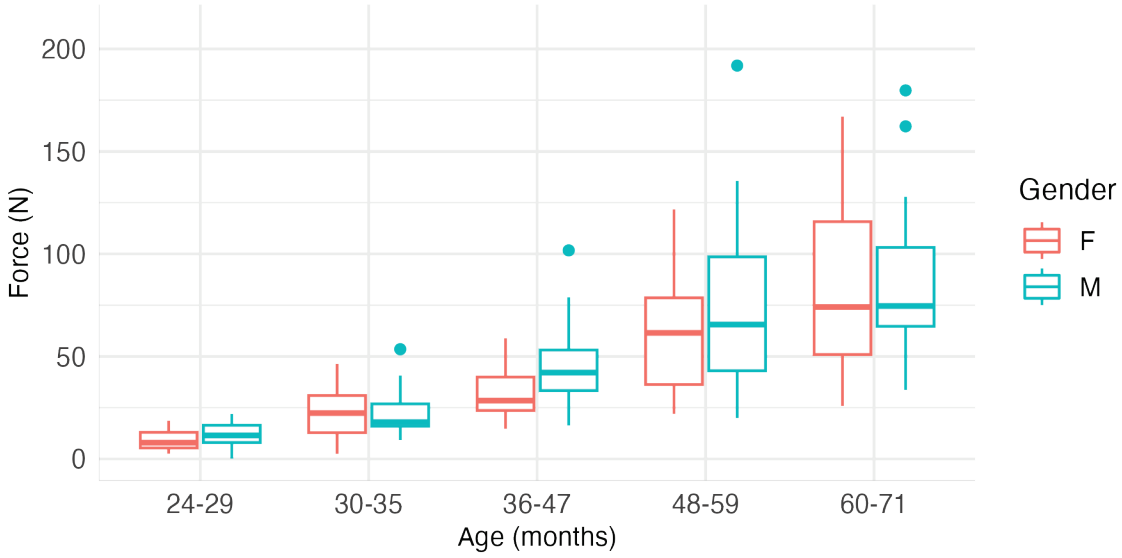
1H_Elbow_Up

Description:	One-hand maximal upward exertion at elbow height
Configuration:	1H_Bar_Stand
Position:	The vertical position of the 1H bar was set to 63% of measured stature, approximately elbow height.
Posture:	Standing
Interface:	1H_Bar_Horz
Units:	Newton



1H_Elbow_Up


Force (N)
200
150
100
50
0
24
30
36
42
48
54
60
66
72
Age (months)
Gender
F
M

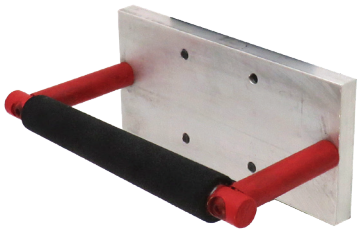

Force (N)
200
150
100
50
0
24-29
30-35
36-47
48-59
60-71
Age (months)
Gender
F
M

1H_Elbow_Up (N)

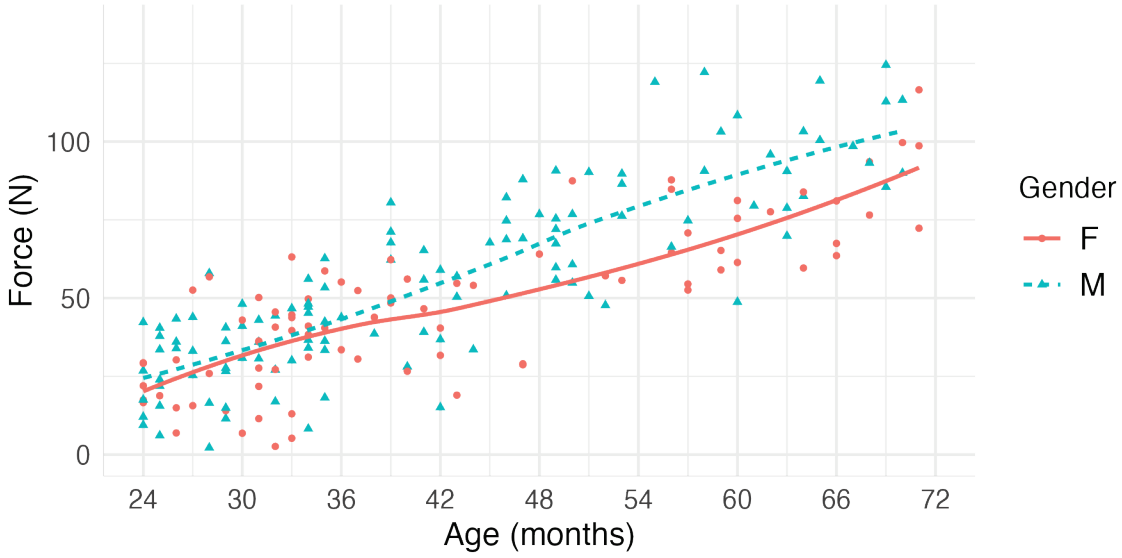
Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	20	11.4	6.7	0.2	0.8	11.5	19.7	22.0
24-29	2.00-2.49	F	12	9.4	5.4	2.6	3.1	7.9	17.4	18.6
24-29	2.00-2.49	Both	32	10.7	6.2	0.2	0.9	10.8	19.0	22.0
30-35	2.50-2.99	M	22	22.4	10.7	9.2	10.9	17.9	40.7	53.5
30-35	2.50-2.99	F	24	22.8	12.2	2.5	4.1	22.4	42.6	46.4
30-35	2.50-2.99	Both	46	22.6	11.4	2.5	9.5	19.7	42.5	53.5
36-47	3.00-3.99	M	22	46.0	20.1	16.4	17.5	42.1	78.4	101.7
36-47	3.00-3.99	F	17	32.5	12.5	14.7	16.0	28.4	50.3	58.9
36-47	3.00-3.99	Both	39	40.1	18.3	14.7	16.4	37.9	70.8	101.7
48-59	4.00-4.99	M	22	73.5	41.3	19.9	26.6	65.5	134.4	191.9
48-59	4.00-4.99	F	12	63.7	31.9	22.0	25.5	61.5	116.8	121.8
48-59	4.00-4.99	Both	34	70.0	38.1	19.9	24.8	61.7	126.6	191.9
60-71	5.00-5.99	M	18	86.2	39.7	33.7	40.4	74.6	164.9	179.8
60-71	5.00-5.99	F	15	83.8	42.8	25.9	38.7	74.1	158.3	167.0
60-71	5.00-5.99	Both	33	85.1	40.5	25.9	38.4	74.4	164.2	179.8

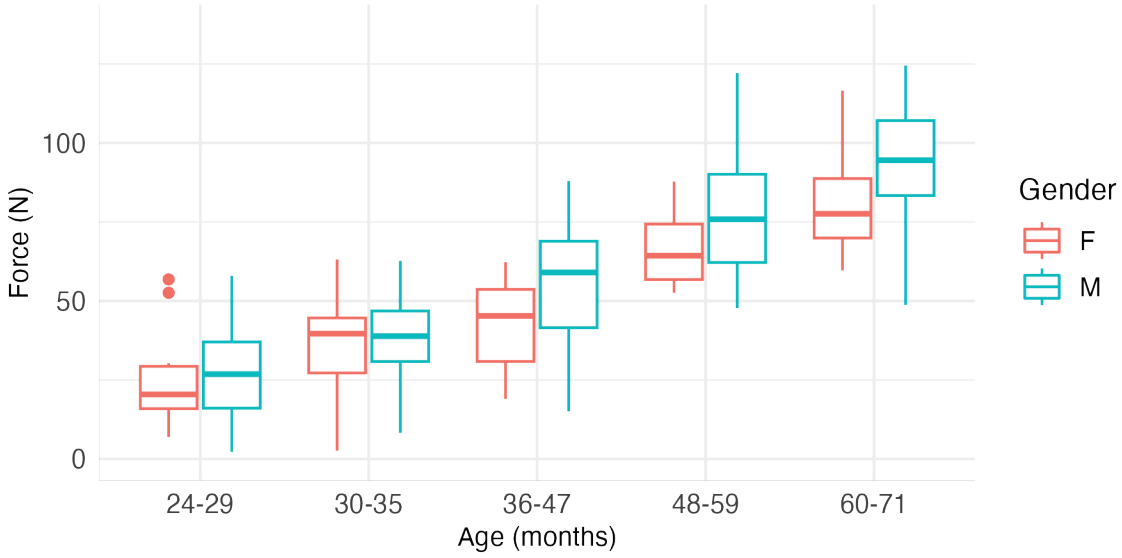
1H_Shoulder_Pull

Description:	One-hand maximal pull exertion at shoulder height
Configuration:	1H_Bar_Stand
Position:	The vertical position of the 1H bar was set to 77% of measured stature, approximately shoulder height.
Posture:	Standing
Interface:	1H_Bar_Horz
Units:	Newton



1H_Shoulder_Pull





1H_Shoulder_Pull (N)

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	27	27.3	13.7	2.2	7.1	26.8	43.8	58.0
24-29	2.00-2.49	F	14	25.1	14.3	6.9	11.6	20.4	54.1	56.8
24-29	2.00-2.49	Both	41	26.5	13.7	2.2	6.9	25.9	52.6	58.0
30-35	2.50-2.99	M	24	38.2	12.8	8.3	17.1	38.9	55.7	62.7
30-35	2.50-2.99	F	25	34.6	16.5	2.6	5.6	39.6	57.0	63.1
30-35	2.50-2.99	Both	49	36.4	14.7	2.6	7.4	39.6	57.7	63.1
36-47	3.00-3.99	M	23	56.8	18.7	15.1	28.7	59.0	82.0	87.9
36-47	3.00-3.99	F	18	42.4	12.7	19.0	25.5	45.3	57.0	62.3
36-47	3.00-3.99	Both	41	50.5	17.7	15.1	26.6	50.9	80.5	87.9
48-59	4.00-4.99	M	22	77.6	20.2	47.7	50.9	75.8	118.3	122.2
48-59	4.00-4.99	F	12	67.0	13.0	52.6	53.6	64.3	87.6	87.8
48-59	4.00-4.99	Both	34	73.9	18.5	47.7	51.9	71.4	108.7	122.2
60-71	5.00-5.99	M	18	94.2	18.7	48.8	66.7	94.5	120.2	124.5
60-71	5.00-5.99	F	15	80.6	15.9	59.6	60.9	77.6	104.7	116.6
60-71	5.00-5.99	Both	33	88.0	18.6	48.8	60.7	85.5	117.7	124.5

1H_Shoulder_Push

Description: One-hand maximal push exertion at shoulder height

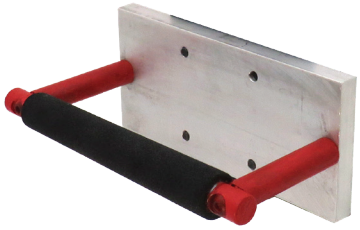
Configuration: 1H_Bar_Stand

Position: The vertical position of the 1H bar was set to 77% of measured stature, approximately shoulder height.

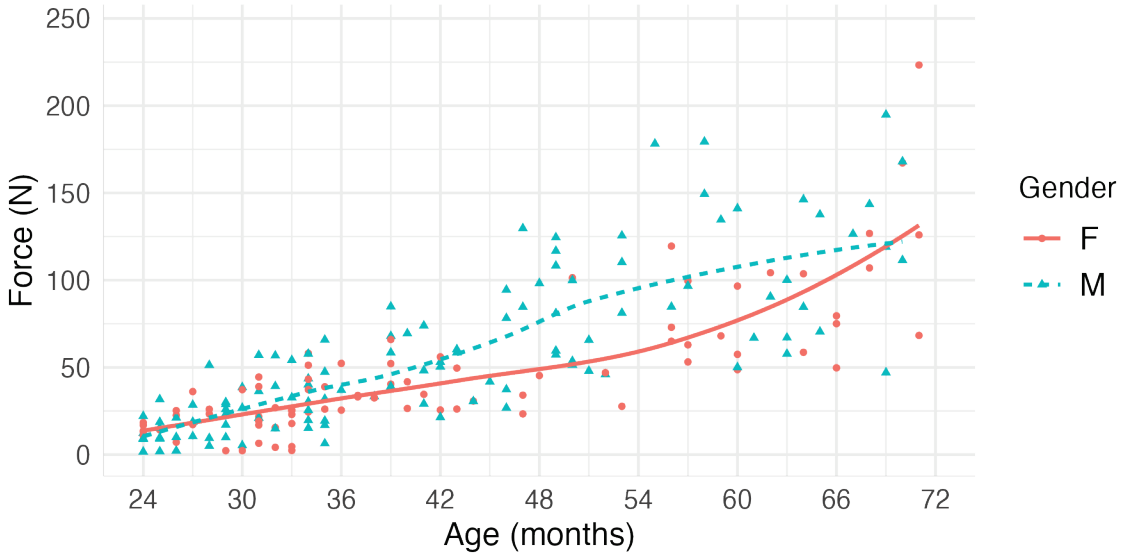
Posture: Standing

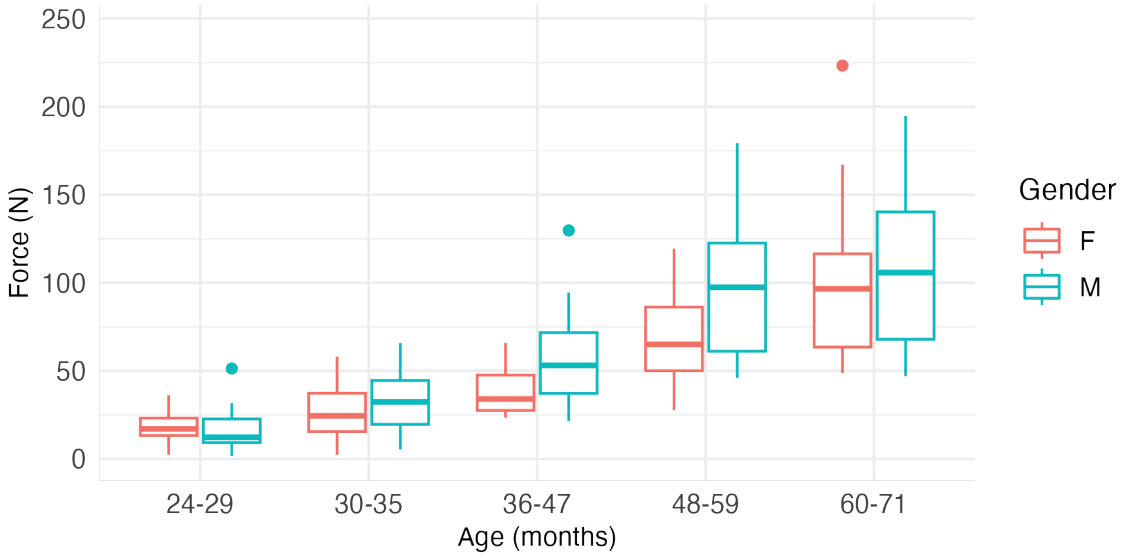
Interface: 1H_Bar_Horz

Units: Newton



1H_Shoulder_Push



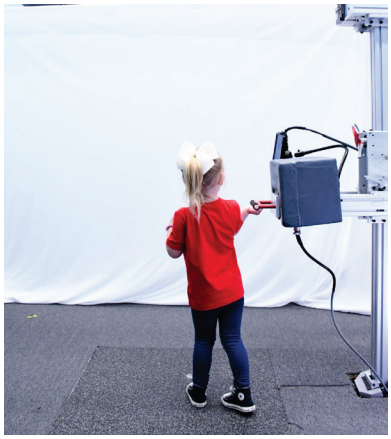


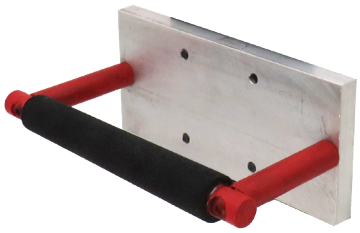
1H_Shoulder_Push (N)

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	27	16.4	11.3	1.7	2.0	12.3	31.2	51.3
24-29	2.00-2.49	F	14	17.7	8.6	2.3	5.4	17.0	29.6	36.2
24-29	2.00-2.49	Both	41	16.8	10.4	1.7	2.2	15.3	31.7	51.3
30-35	2.50-2.99	M	24	33.5	17.1	5.3	7.7	32.4	57.7	65.9
30-35	2.50-2.99	F	25	25.1	15.5	2.3	2.8	24.5	49.9	58.1
30-35	2.50-2.99	Both	49	29.2	16.7	2.3	4.4	26.1	57.5	65.9
36-47	3.00-3.99	M	23	56.9	26.1	21.4	27.1	53.1	93.5	129.7
36-47	3.00-3.99	F	18	38.0	12.4	23.4	25.2	34.0	57.6	66.0
36-47	3.00-3.99	Both	41	48.6	23.0	21.4	25.5	41.8	84.9	129.7
48-59	4.00-4.99	M	22	97.8	39.9	46.0	48.1	97.4	176.8	179.4
48-59	4.00-4.99	F	11	69.3	27.6	27.7	36.5	65.0	110.5	119.5
48-59	4.00-4.99	Both	33	88.3	38.3	27.7	45.7	81.2	160.9	179.4
60-71	5.00-5.99	M	18	106.8	43.1	47.1	49.6	105.8	172.1	194.9
60-71	5.00-5.99	F	15	99.5	47.7	48.7	49.4	96.6	184.0	223.3
60-71	5.00-5.99	Both	33	103.5	44.7	47.1	49.3	100.1	178.8	223.3

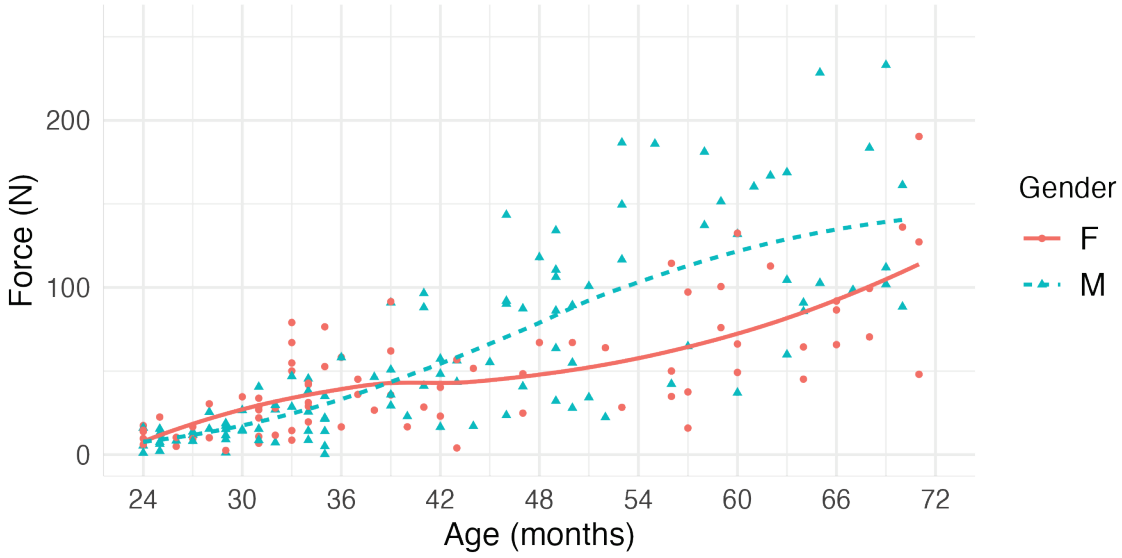
1H_Shoulder_Up

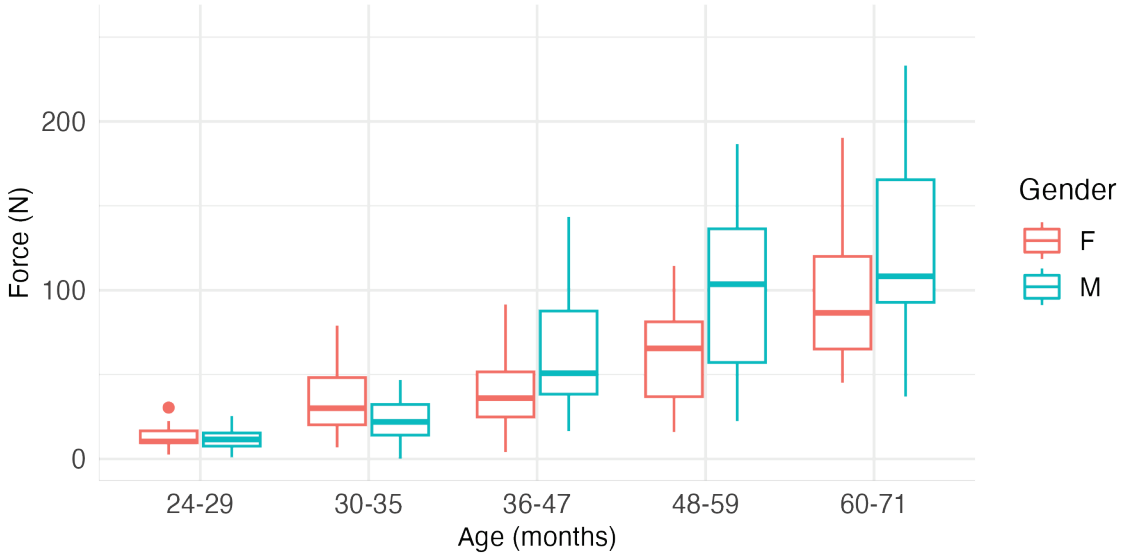
Description:	One-hand maximal upward exertion at shoulder height
Configuration:	1H_Bar_Stand
Position:	The vertical position of the 1H bar was set to 77% of measured stature, approximately shoulder height.
Posture:	Standing
Interface:	1H_Bar_Horz
Units:	Newton





1H_Shoulder_Up



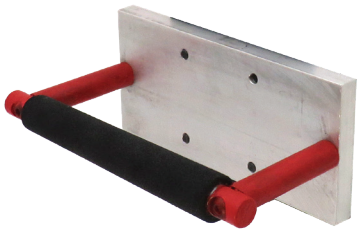


1H_Shoulder_Up (N)

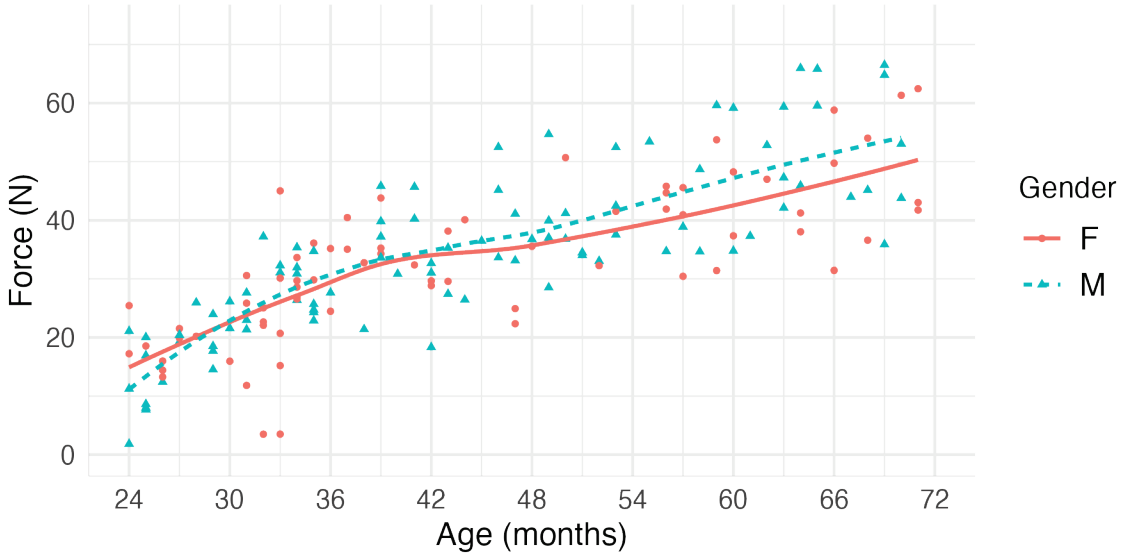
Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	21	11.1	6.2	1.0	1.2	11.6	18.8	25.5
24-29	2.00-2.49	F	13	13.0	7.6	2.5	4.0	10.4	25.7	30.4
24-29	2.00-2.49	Both	34	11.8	6.7	1.0	1.8	11.5	23.5	30.4
30-35	2.50-2.99	M	23	22.9	13.4	0.2	5.3	21.9	45.0	46.9
30-35	2.50-2.99	F	22	35.0	21.1	6.8	8.8	30.1	76.0	79.1
30-35	2.50-2.99	Both	45	28.8	18.5	0.2	6.9	26.9	64.6	79.1
36-47	3.00-3.99	M	23	57.9	31.6	16.5	17.6	50.8	96.0	143.4
36-47	3.00-3.99	F	17	39.2	21.3	4.0	14.1	36.0	67.9	91.5
36-47	3.00-3.99	Both	40	49.9	28.9	4.0	16.6	45.8	92.2	143.4
48-59	4.00-4.99	M	22	99.8	52.7	22.4	28.1	103.5	185.7	186.6
48-59	4.00-4.99	F	12	62.7	30.9	15.9	22.7	65.5	106.8	114.5
48-59	4.00-4.99	Both	34	86.7	49.1	15.9	26.0	81.0	182.8	186.6
60-71	5.00-5.99	M	18	128.6	54.4	37.0	56.4	108.2	229.2	233.1
60-71	5.00-5.99	F	15	92.4	41.0	45.2	47.2	86.6	152.4	190.4
60-71	5.00-5.99	Both	33	112.2	51.4	37.0	46.9	101.9	205.6	233.1

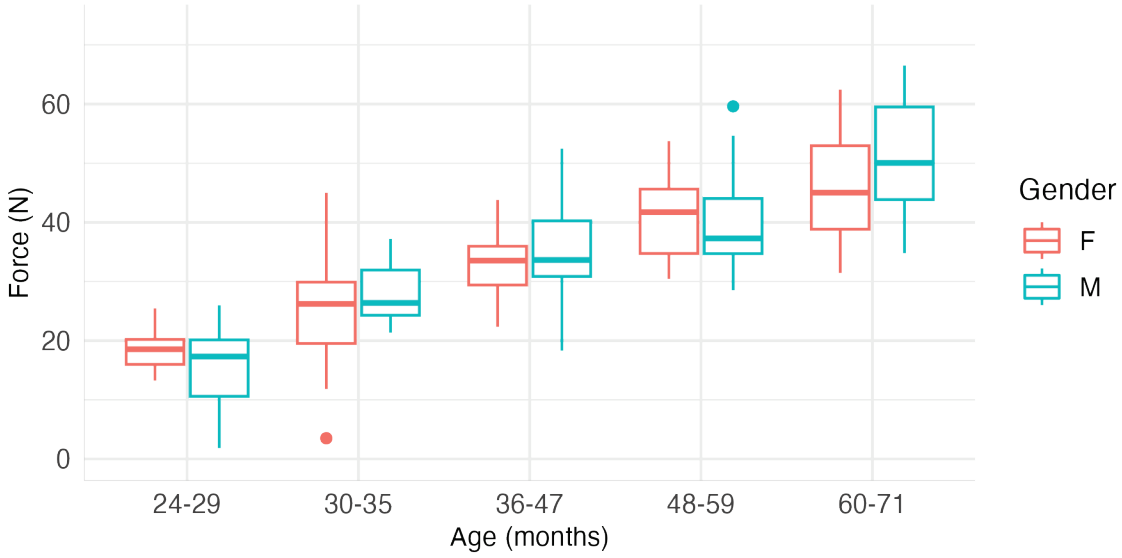
1H_OverHead_Pull

Description:	One-hand maximal pull exertion at overhead height
Configuration:	1H_Bar_Stand
Position:	The vertical position of the 1H bar was set to 110% of measured stature, approximately overhead height.
Posture:	Standing
Interface:	1H_Bar_Horz
Units:	Newton



1H_OverHead_Pull



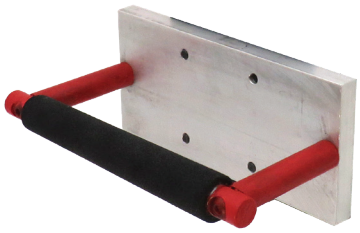


1H_OverHead_Pull (N)

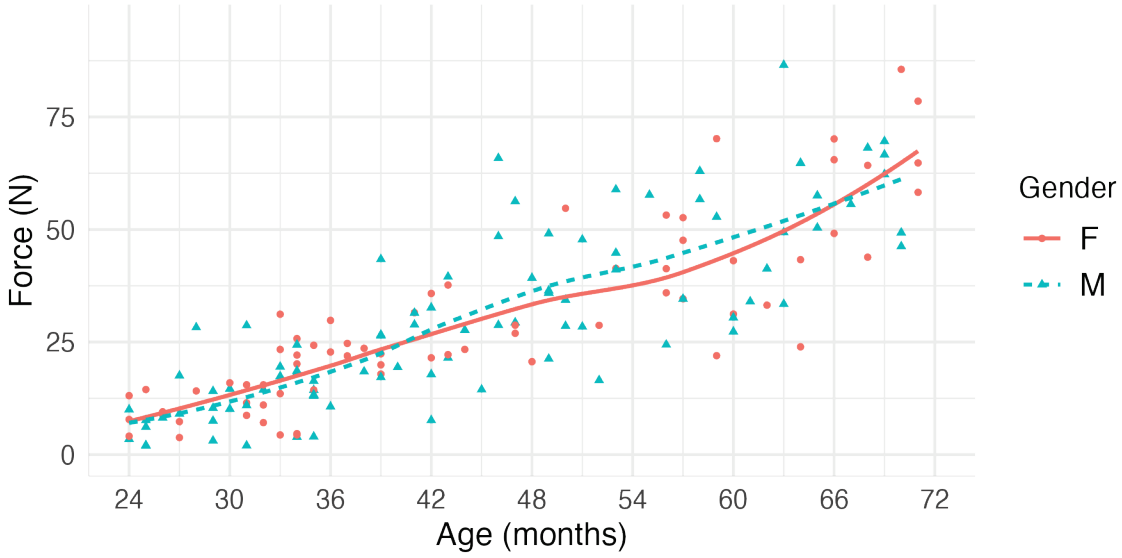
Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	16	15.5	6.7	1.8	6.2	17.3	24.5	26.0
24-29	2.00-2.49	F	9	18.5	3.8	13.3	13.7	18.5	23.9	25.4
24-29	2.00-2.49	Both	25	16.6	5.9	1.8	7.7	17.7	25.1	26.0
30-35	2.50-2.99	M	17	28.1	5.1	21.4	21.5	26.4	35.7	37.2
30-35	2.50-2.99	F	20	24.2	10.3	3.5	3.5	26.2	36.6	45.0
30-35	2.50-2.99	Both	37	26.0	8.4	3.5	10.2	26.4	36.3	45.0
36-47	3.00-3.99	M	21	35.0	8.5	18.3	21.4	33.6	45.8	52.5
36-47	3.00-3.99	F	16	33.0	6.1	22.3	23.9	33.5	41.3	43.8
36-47	3.00-3.99	Both	37	34.1	7.5	18.3	22.2	33.6	45.7	52.5
48-59	4.00-4.99	M	20	40.8	8.5	28.5	32.8	37.3	54.9	59.6
48-59	4.00-4.99	F	12	41.2	7.5	30.4	31.0	41.7	52.1	53.7
48-59	4.00-4.99	Both	32	40.9	8.0	28.5	31.0	39.4	54.2	59.6
60-71	5.00-5.99	M	18	51.3	10.9	34.8	35.7	50.0	66.0	66.5
60-71	5.00-5.99	F	14	46.5	9.8	31.4	34.8	45.0	61.7	62.5
60-71	5.00-5.99	Both	32	49.2	10.5	31.4	35.4	47.1	65.9	66.5

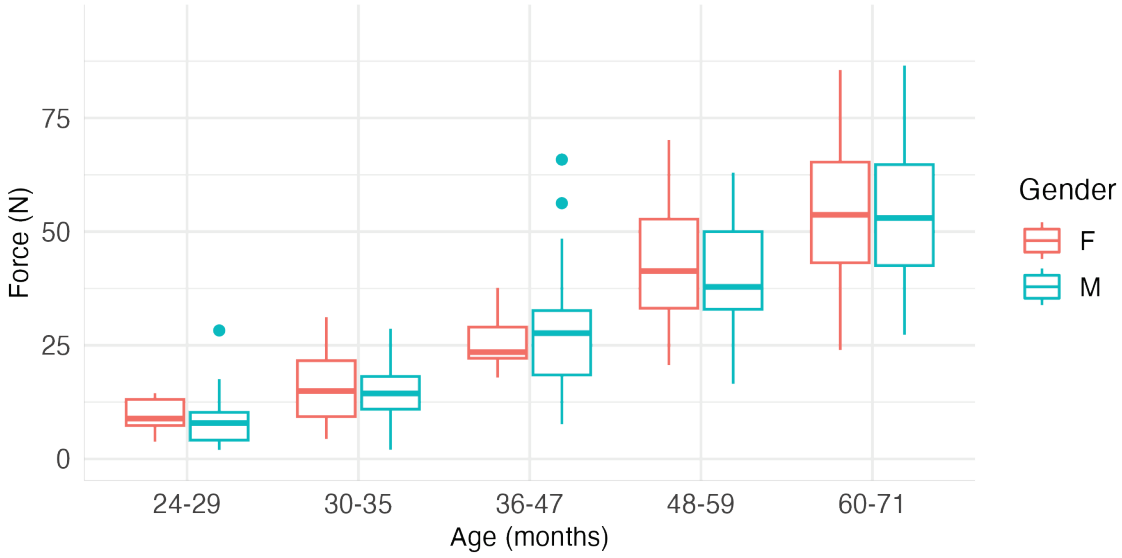
1H_OverHead_Push

Description:	One-hand maximal push exertion at overhead height
Configuration:	1H_Bar_Stand
Position:	The vertical position of the 1H bar was set to 110% of measured stature, approximately overhead height.
Posture:	Standing
Interface:	1H_Bar_Horz
Units:	Newton



1H_OverHead_Push





1H_OverHead_Push (N)

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	14	9.2	7.1	2.0	2.0	7.9	21.3	28.3
24-29	2.00-2.49	F	9	9.2	4.0	3.8	3.9	8.9	14.3	14.5
24-29	2.00-2.49	Both	23	9.2	5.9	2.0	2.2	8.2	17.3	28.3
30-35	2.50-2.99	M	17	14.3	7.0	2.0	3.5	14.4	25.3	28.7
30-35	2.50-2.99	F	18	15.2	8.0	4.4	4.4	14.9	26.6	31.2
30-35	2.50-2.99	Both	35	14.8	7.4	2.0	4.0	14.4	26.6	31.2
36-47	3.00-3.99	M	21	29.2	14.8	7.6	10.7	27.7	56.3	65.9
36-47	3.00-3.99	F	16	25.7	5.6	17.9	19.4	23.5	36.3	37.7
36-47	3.00-3.99	Both	37	27.7	11.7	7.6	13.7	26.4	50.0	65.9
48-59	4.00-4.99	M	20	40.4	13.2	16.5	21.1	37.8	59.1	63.0
48-59	4.00-4.99	F	12	41.9	14.6	20.7	21.4	41.3	61.7	70.2
48-59	4.00-4.99	Both	32	41.0	13.5	16.5	21.0	40.2	60.7	70.2
60-71	5.00-5.99	M	18	53.2	16.0	27.3	30.0	53.0	72.1	86.5
60-71	5.00-5.99	F	14	53.9	18.5	23.9	28.7	53.7	81.0	85.6
60-71	5.00-5.99	Both	32	53.5	16.8	23.9	29.0	53.0	81.7	86.5

2H_Thigh_Pull

Description: Two-hand maximal pull exertion at thigh height

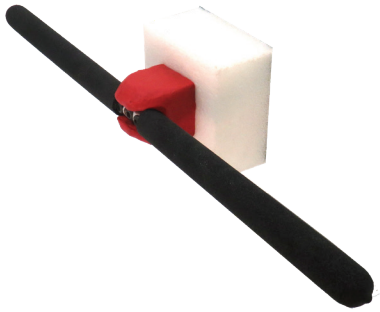
Configuration: 2H_Bar_Stand

Position: The vertical position of the 2H bar was set to 41% of measured stature, approximately mid-thigh height.

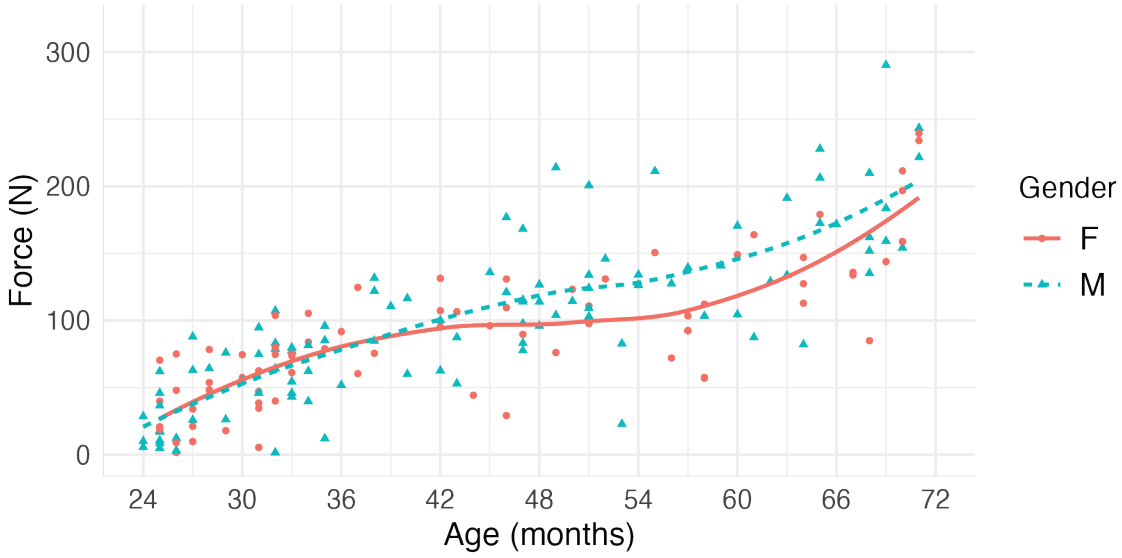
Posture: Standing

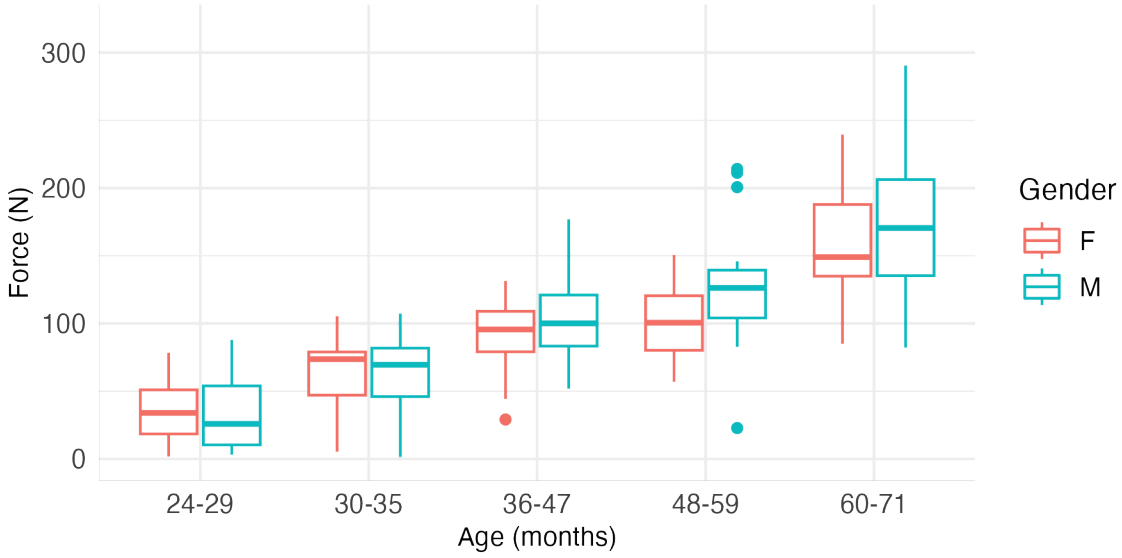
Interface: 2H_Bar_Horz

Units: Newton



2H_Thigh_Pull





2H_Thigh_Pull (N)

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	19	31.9	26.7	3.1	4.7	25.9	77.2	87.9
24-29	2.00-2.49	F	15	36.5	25.1	1.7	6.8	34.0	76.1	78.4
24-29	2.00-2.49	Both	34	33.9	25.7	1.7	4.2	26.1	76.8	87.9
30-35	2.50-2.99	M	20	64.1	27.3	1.6	11.5	69.5	96.4	107.3
30-35	2.50-2.99	F	17	64.5	25.6	5.4	28.7	73.7	104.2	105.4
30-35	2.50-2.99	Both	37	64.3	26.2	1.6	10.7	73.7	104.2	107.3
36-47	3.00-3.99	M	21	103.2	34.0	51.8	53.0	100.1	168.2	176.9
36-47	3.00-3.99	F	14	92.3	30.9	29.1	39.0	95.6	131.1	131.4
36-47	3.00-3.99	Both	35	98.8	32.8	29.1	49.6	97.6	145.6	176.9
48-59	4.00-4.99	M	21	127.3	43.0	22.8	82.7	126.3	211.3	214.1
48-59	4.00-4.99	F	14	100.3	28.0	57.0	57.4	100.6	137.8	150.6
48-59	4.00-4.99	Both	35	116.5	39.6	22.8	57.4	114.0	203.8	214.1
60-71	5.00-5.99	M	21	170.9	51.6	82.1	87.4	170.5	243.5	290.4
60-71	5.00-5.99	F	15	161.2	43.8	85.0	104.5	149.0	235.7	239.6
60-71	5.00-5.99	Both	36	166.9	48.1	82.1	86.8	160.6	240.5	290.4

2H_Thigh_Push

Description: Two-hand maximal push exertion at thigh height

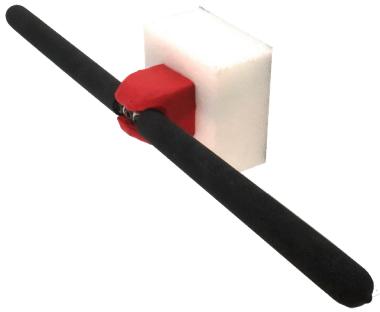
Configuration: 2H_Bar_Stand

Position: The vertical position of the 2H bar was set to 41% of measured stature, approximately mid-thigh height.

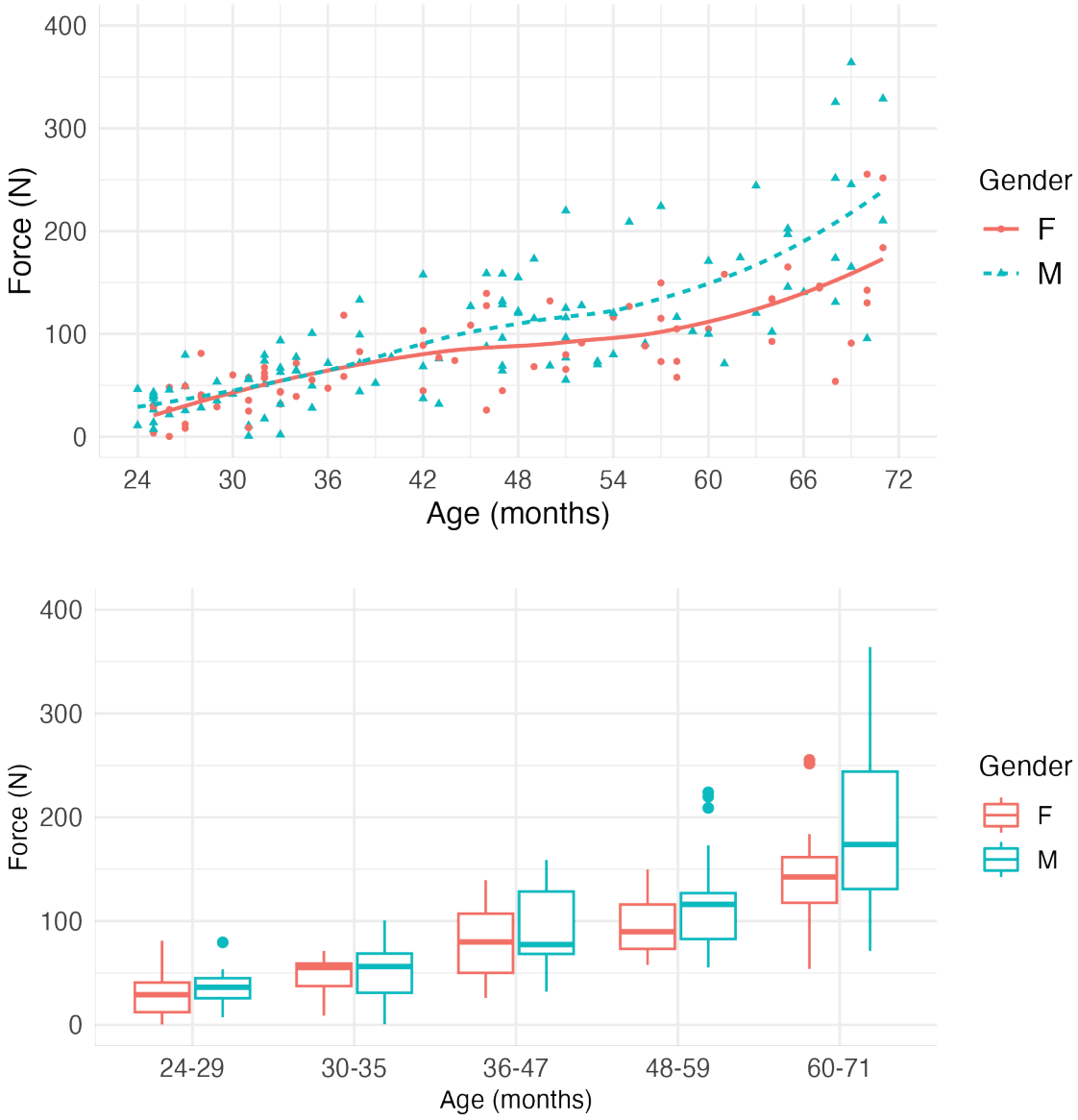
Posture: Standing

Interface: 2H_Bar_Horz

Units: Newton



2H_Thigh_Push

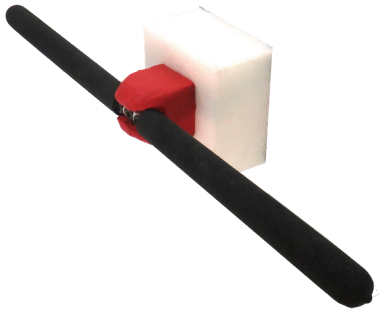


2H_Thigh_Push (N)

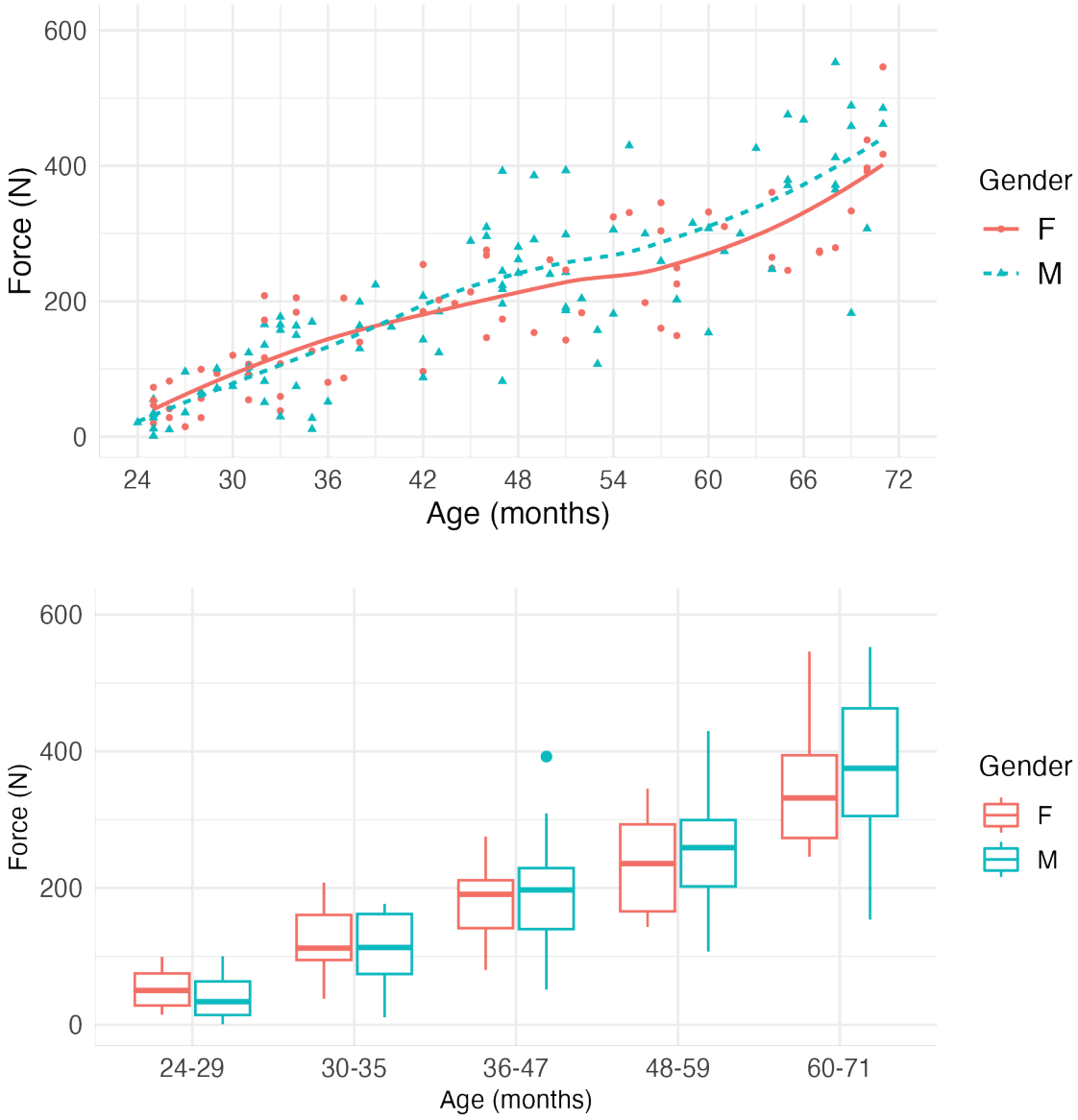
Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	18	35.3	17.3	7.3	10.4	36.2	57.4	79.5
24-29	2.00-2.49	F	13	30.3	22.1	0.4	2.3	29.0	62.0	81.1
24-29	2.00-2.49	Both	31	33.2	19.3	0.4	5.5	32.2	66.5	81.1
30-35	2.50-2.99	M	20	51.4	28.8	0.6	2.0	56.2	93.9	100.7
30-35	2.50-2.99	F	15	47.7	17.3	8.7	20.1	55.2	68.6	71.4
30-35	2.50-2.99	Both	35	49.8	24.3	0.6	6.7	55.7	83.6	100.7
36-47	3.00-3.99	M	21	92.4	40.5	31.8	37.2	77.4	158.4	158.8
36-47	3.00-3.99	F	14	81.5	34.7	25.9	38.1	79.9	131.7	139.5
36-47	3.00-3.99	Both	35	88.0	38.1	25.9	35.6	77.4	157.8	158.8
48-59	4.00-4.99	M	22	120.8	48.6	55.2	69.2	116.1	219.3	224.1
48-59	4.00-4.99	F	14	95.8	28.5	57.8	62.8	89.7	138.2	149.6
48-59	4.00-4.99	Both	36	111.1	43.2	55.2	63.6	110.0	211.7	224.1
60-71	5.00-5.99	M	21	188.5	81.1	71.1	95.5	173.8	328.9	364.1
60-71	5.00-5.99	F	15	145.9	54.6	53.9	79.9	142.5	252.8	255.4
60-71	5.00-5.99	Both	36	170.7	73.5	53.9	86.1	152.3	326.3	364.1

2H_Thigh_Up

Description:	Two-hand maximal upward exertion at thigh height
Configuration:	2H_Bar_Stand
Position:	The vertical position of the 2H bar was set to 41% of measured stature, approximately mid-thigh height.
Posture:	Standing
Interface:	2H_Bar_Horz
Units:	Newton



2H_Thigh_Up

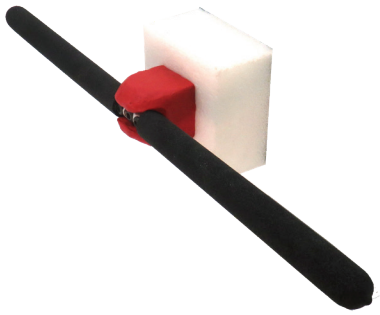

600
400
200
0
Force (N)
24
30
36
42
48
54
60
66
72
Age (months)
Gender
F
M
600
400
200
0
Force (N)
24-29
30-35
36-47
48-59
60-71
Age (months)
Gender
F
M

2H_Thigh_Up (N)

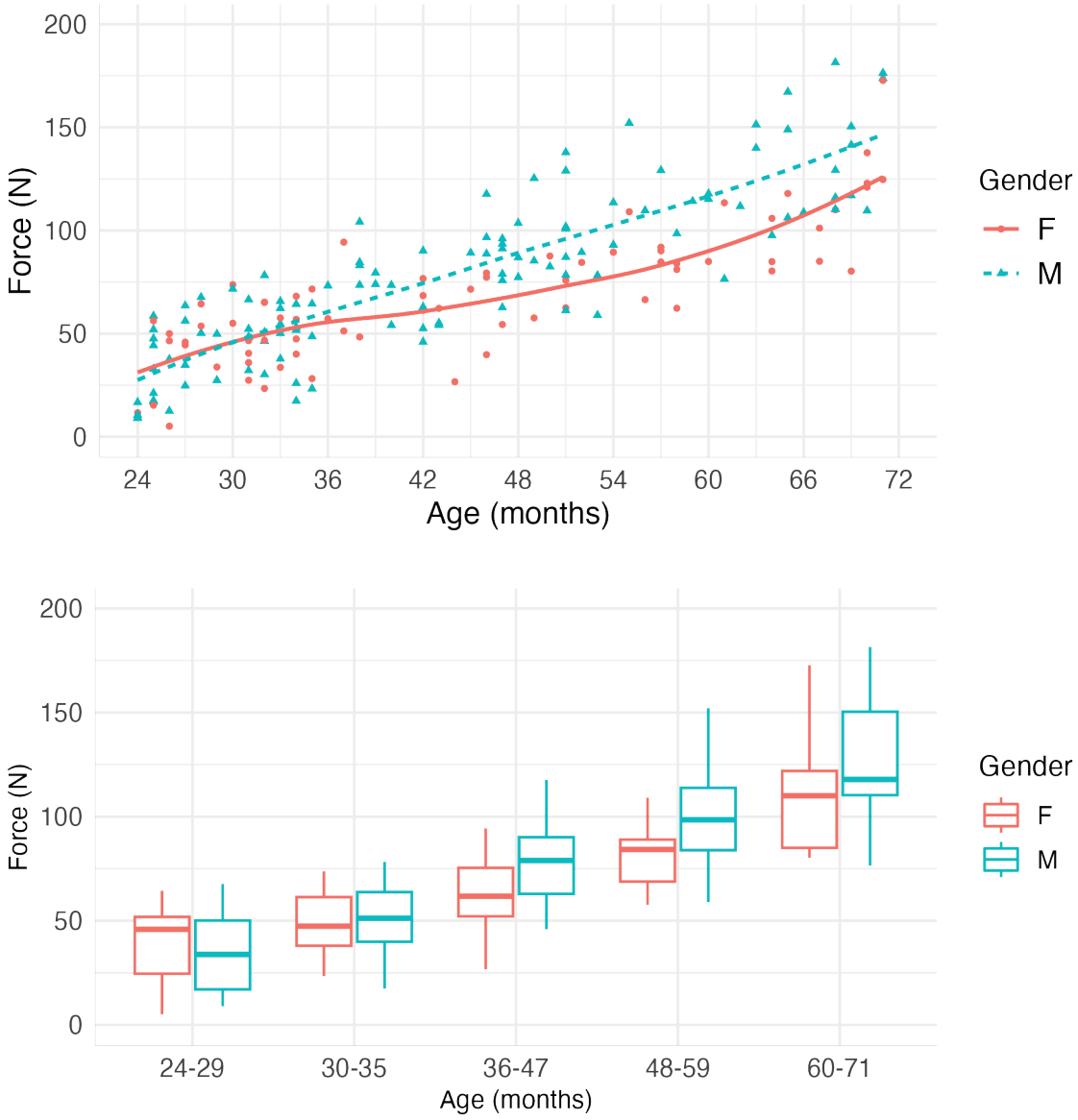
Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	14	40.5	32.8	0.9	1.2	33.9	97.5	100.5
24-29	2.00-2.49	F	12	53.1	28.6	14.8	17.6	50.3	96.1	99.5
24-29	2.00-2.49	Both	26	46.3	31.0	0.9	3.7	38.5	98.6	100.5
30-35	2.50-2.99	M	18	108.6	55.3	11.1	25.0	113.1	170.6	177.1
30-35	2.50-2.99	F	14	121.3	54.0	38.2	48.8	112.2	206.3	208.3
30-35	2.50-2.99	Both	32	114.1	54.2	11.1	28.6	112.2	193.4	208.3
36-47	3.00-3.99	M	20	196.4	84.2	51.4	80.5	197.4	313.6	392.3
36-47	3.00-3.99	F	14	180.2	64.1	80.3	84.5	190.9	270.6	275.7
36-47	3.00-3.99	Both	34	189.8	76.0	51.4	81.4	196.5	300.7	392.3
48-59	4.00-4.99	M	21	260.6	80.5	107.2	157.2	259.2	393.1	429.9
48-59	4.00-4.99	F	14	233.9	72.0	142.8	147.0	235.9	336.1	345.6
48-59	4.00-4.99	Both	35	250.0	77.3	107.2	147.3	246.2	388.0	429.9
60-71	5.00-5.99	M	20	374.3	107.9	153.7	180.9	375.2	491.9	552.6
60-71	5.00-5.99	F	15	340.8	84.9	245.6	247.8	331.8	470.5	546.1
60-71	5.00-5.99	Both	35	359.9	98.8	153.7	226.6	364.7	505.9	552.6

2H_Elbow_Pull

Description:	Two-hand maximal pull exertion at elbow height
Configuration:	2H_Bar_Stand
Position:	The vertical position of the 2H bar was set to 63% of measured stature, approximately elbow height.
Posture:	Standing
Interface:	2H_Bar_Horz
Units:	Newton



2H_Elbow_Pull

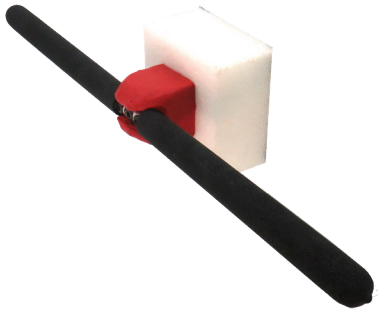


2H_Elbow_Pull (N)

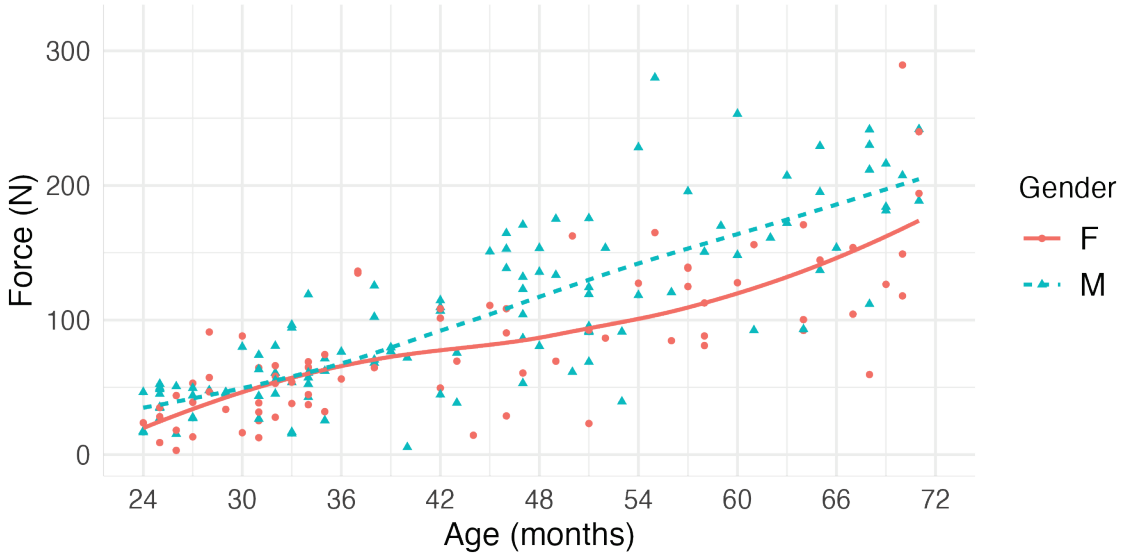
Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	22	34.6	19.1	9.0	9.2	33.8	63.3	67.6
24-29	2.00-2.49	F	11	38.8	19.7	5.1	8.3	45.9	60.3	64.4
24-29	2.00-2.49	Both	33	36.0	19.1	5.1	9.1	37.6	63.9	67.6
30-35	2.50-2.99	M	22	49.8	16.4	17.4	23.4	51.2	71.4	78.3
30-35	2.50-2.99	F	19	49.0	15.5	23.4	27.0	47.4	71.8	73.7
30-35	2.50-2.99	Both	41	49.4	15.8	17.4	23.4	50.1	71.7	78.3
36-47	3.00-3.99	M	25	78.0	17.9	46.0	52.8	78.9	102.7	117.7
36-47	3.00-3.99	F	14	62.1	17.7	26.7	35.2	61.8	84.6	94.3
36-47	3.00-3.99	Both	39	72.3	19.2	26.7	45.3	73.5	97.4	117.7
48-59	4.00-4.99	M	23	99.7	24.0	58.9	62.8	98.5	137.0	152.1
48-59	4.00-4.99	F	14	80.5	14.2	57.6	60.7	84.2	97.9	109.1
48-59	4.00-4.99	Both	37	92.5	22.7	57.6	60.8	87.6	130.9	152.1
60-71	5.00-5.99	M	21	130.8	28.6	76.5	97.6	117.9	176.4	181.5
60-71	5.00-5.99	F	15	109.5	25.4	80.3	80.3	110.0	148.2	172.8
60-71	5.00-5.99	Both	36	121.9	28.9	76.5	80.3	116.5	174.4	181.5

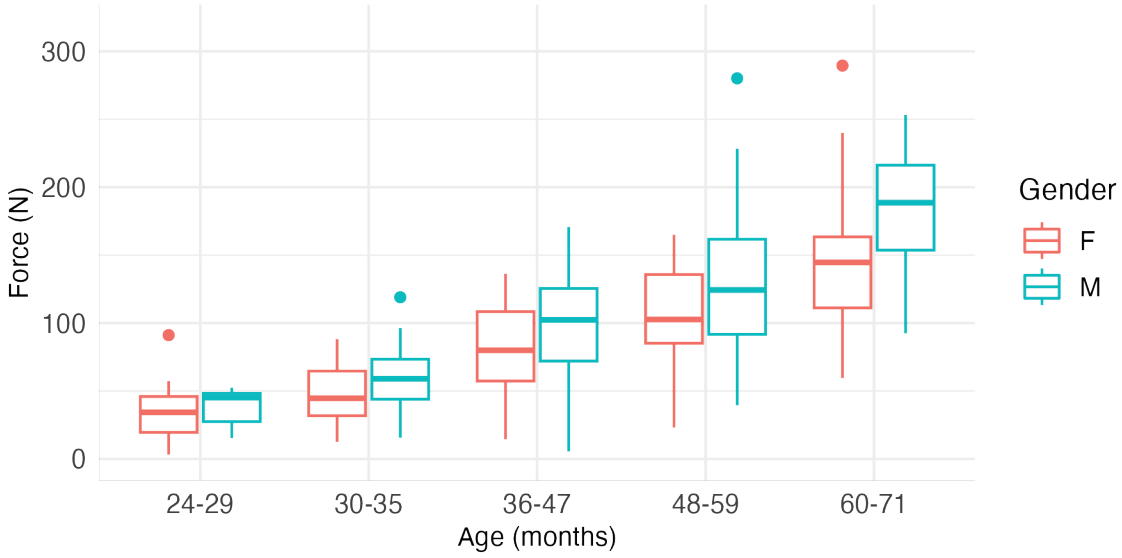
2H_Elbow_Push

Description:	Two-hand maximal push exertion at elbow height
Configuration:	2H_Bar_Stand
Position:	The vertical position of the 2H bar was set to 63% of measured stature, approximately elbow height.
Posture:	Standing
Interface:	2H_Bar_Horz
Units:	Newton



2H_Elbow_Push



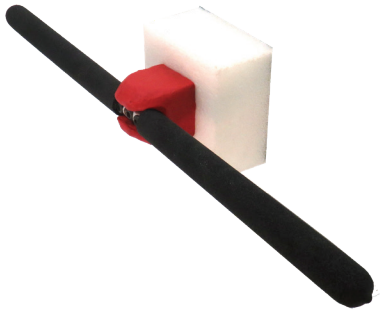


2H_Elbow_Push (N)

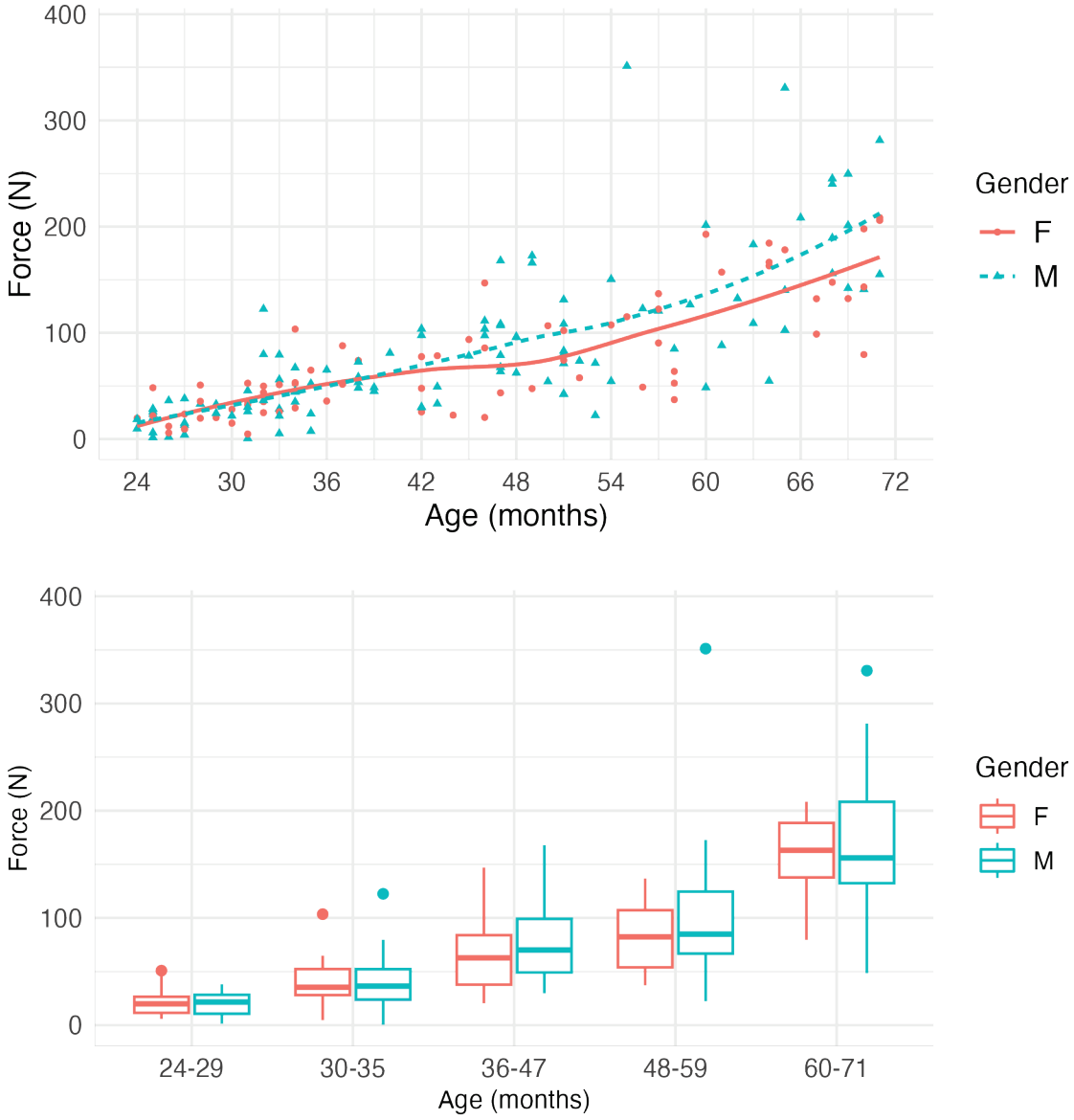
Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	19	38.3	12.7	15.3	16.4	45.2	50.9	52.6
24-29	2.00-2.49	F	14	35.4	22.9	3.2	6.9	34.3	69.1	91.1
24-29	2.00-2.49	Both	33	37.0	17.5	3.2	11.5	38.9	54.8	91.1
30-35	2.50-2.99	M	22	59.0	26.0	15.6	17.2	59.0	96.3	119.0
30-35	2.50-2.99	F	19	47.2	20.8	12.6	15.9	44.6	75.8	88.2
30-35	2.50-2.99	Both	41	53.5	24.2	12.6	16.3	53.9	94.3	119.0
36-47	3.00-3.99	M	25	97.7	41.5	5.5	39.7	102.3	162.2	170.7
36-47	3.00-3.99	F	14	81.0	37.7	14.4	23.8	80.0	135.4	136.4
36-47	3.00-3.99	Both	39	91.7	40.5	5.5	27.4	90.5	154.1	170.7
48-59	4.00-4.99	M	23	132.8	55.9	39.4	62.1	124.4	225.0	280.1
48-59	4.00-4.99	F	14	106.9	39.1	23.1	53.2	102.6	163.4	165.0
48-59	4.00-4.99	Both	37	123.0	51.2	23.1	57.0	120.6	202.1	280.1
60-71	5.00-5.99	M	21	183.7	47.7	92.4	93.1	188.6	241.8	253.2
60-71	5.00-5.99	F	15	148.4	58.6	59.5	82.4	144.6	254.8	289.5
60-71	5.00-5.99	Both	36	169.0	54.7	59.5	92.4	166.0	244.6	289.5

2H_Elbow_Up

Description:	Two-hand maximal upward exertion at elbow height
Configuration:	2H_Bar_Stand
Position:	The vertical position of the 2H bar was set to 63% of measured stature, approximately elbow height.
Posture:	Standing
Interface:	2H_Bar_Horz
Units:	Newton



2H_Elbow_Up

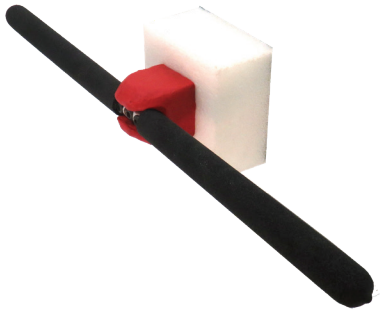

Force (N)
400
300
200
100
0
24
30
36
42
48
54
60
66
72
Age (months)
Gender
F
M
Force (N)
400
300
200
100
0
24-29
30-35
36-47
48-59
60-71
Age (months)
Gender
F
M

2H_Elbow_Up (N)

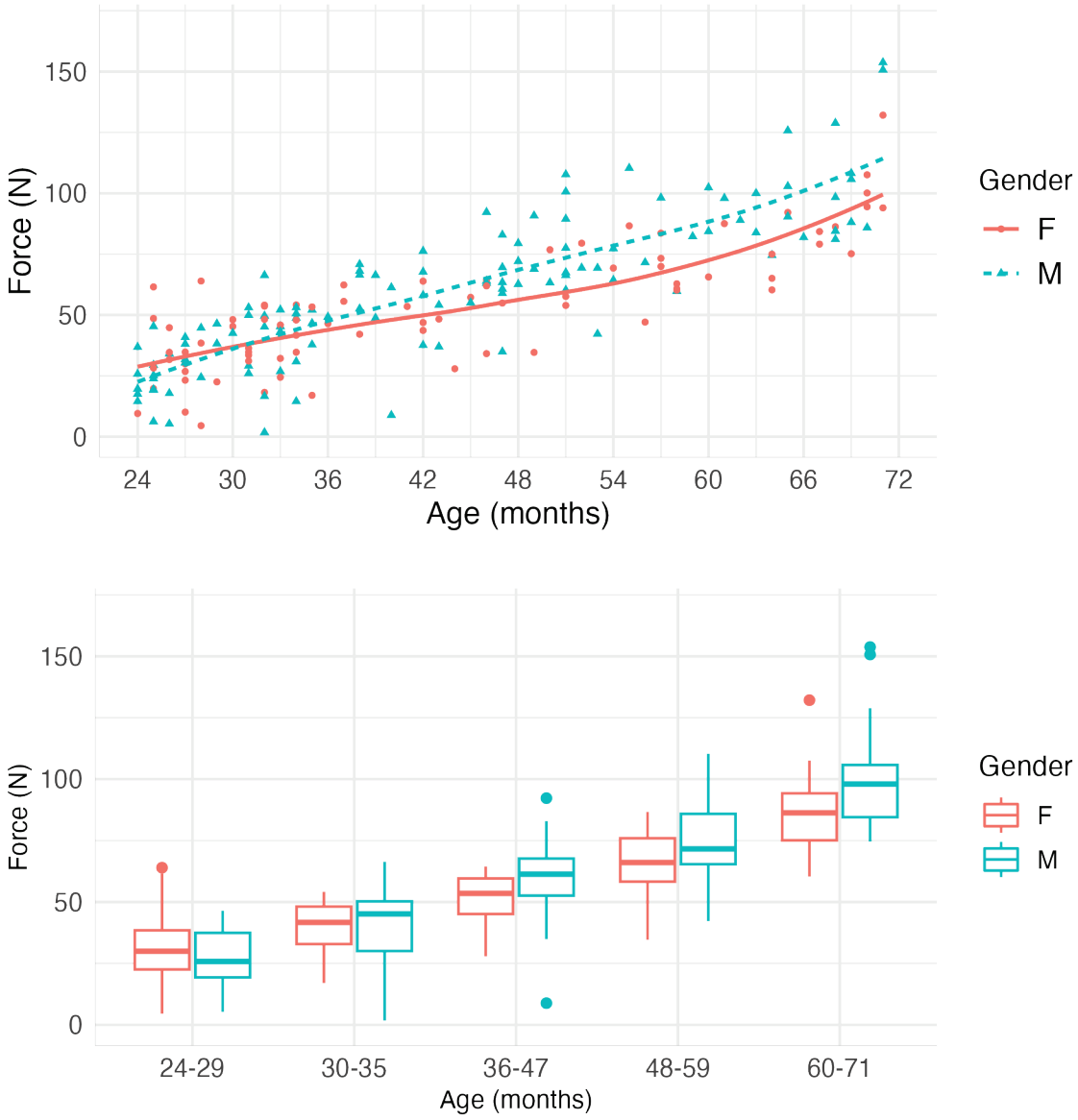
Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	18	20.0	11.9	1.5	1.9	21.6	36.5	38.1
24-29	2.00-2.49	F	12	23.0	14.7	5.8	7.7	19.9	49.5	50.9
24-29	2.00-2.49	Both	30	21.2	13.0	1.5	2.9	19.9	43.7	50.9
30-35	2.50-2.99	M	21	41.4	28.6	0.5	5.2	36.4	79.8	122.5
30-35	2.50-2.99	F	17	41.3	22.4	4.7	12.9	35.4	72.6	103.6
30-35	2.50-2.99	Both	38	41.3	25.7	0.5	5.1	35.9	83.3	122.5
36-47	3.00-3.99	M	24	75.0	32.7	29.8	30.6	70.1	110.9	167.9
36-47	3.00-3.99	F	14	63.7	35.1	20.4	21.7	62.8	112.4	146.9
36-47	3.00-3.99	Both	38	70.8	33.6	20.4	25.1	70.1	116.7	167.9
48-59	4.00-4.99	M	23	103.7	67.2	22.4	42.2	84.9	172.0	351.2
48-59	4.00-4.99	F	14	83.1	32.4	37.1	43.9	82.4	127.4	136.9
48-59	4.00-4.99	Both	37	95.9	56.9	22.4	41.2	84.9	167.3	351.2
60-71	5.00-5.99	M	21	171.4	72.9	48.5	54.7	156.0	281.3	330.7
60-71	5.00-5.99	F	15	159.2	37.9	79.6	93.0	163.1	206.7	208.5
60-71	5.00-5.99	Both	36	166.3	60.4	48.5	73.4	160.1	257.6	330.7

2H_Shoulder_Pull

Description:	Two-hand maximal pull exertion at shoulder height
Configuration:	2H_Bar_Stand
Position:	The vertical position of the 2H bar was set to 77% of measured stature, approximately shoulder height.
Posture:	Standing
Interface:	2H_Bar_Horz
Units:	Newton



2H_Shoulder_Pull

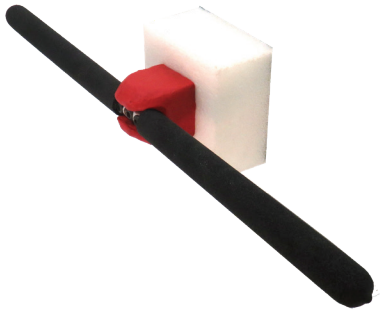


2H_Shoulder_Pull (N)

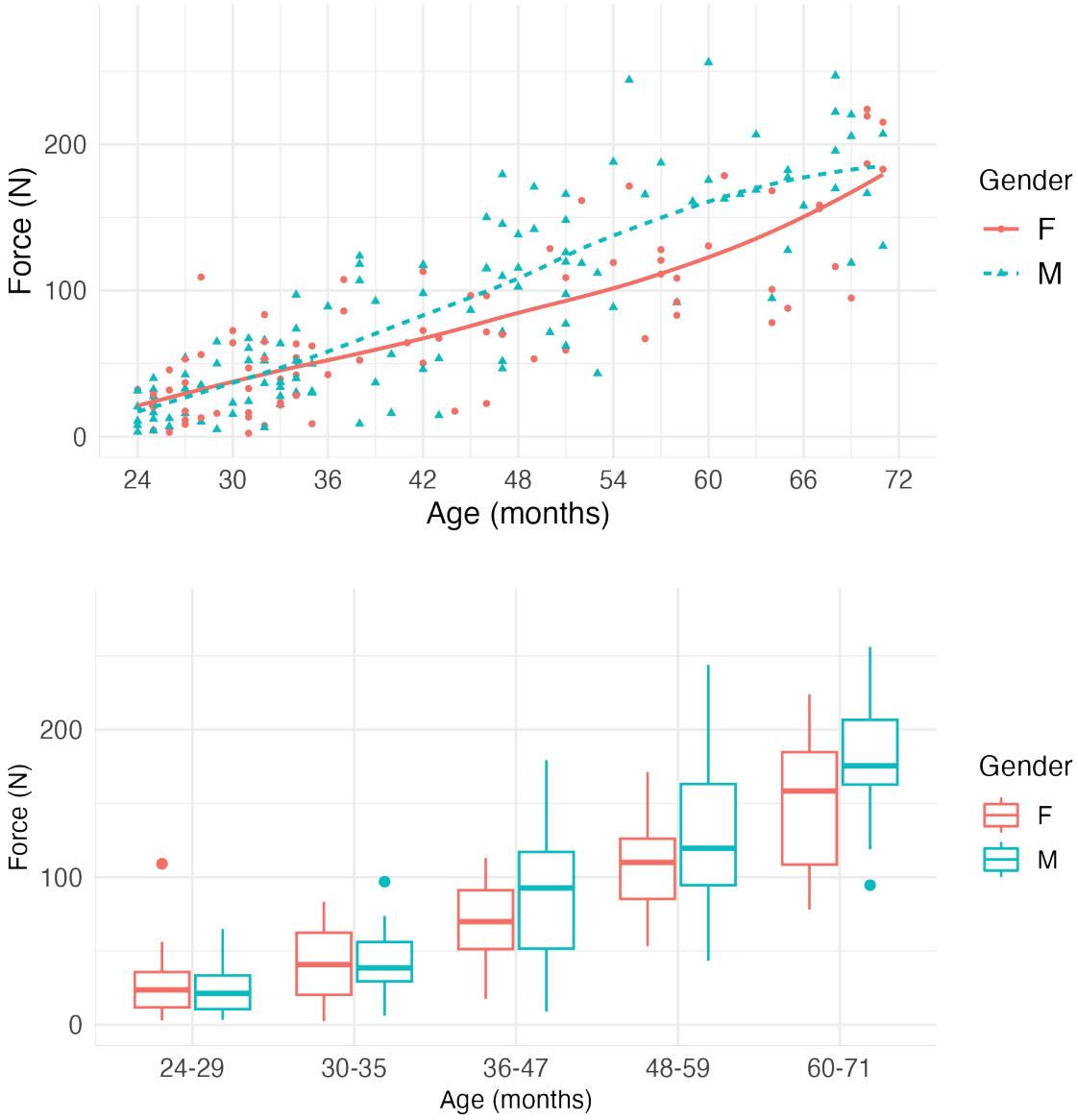
Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	23	27.6	11.8	5.3	7.0	25.8	45.2	46.4
24-29	2.00-2.49	F	17	31.4	16.7	4.5	8.5	30.0	62.0	64.0
24-29	2.00-2.49	Both	40	29.2	14.0	4.5	6.2	28.8	49.2	64.0
30-35	2.50-2.99	M	23	40.2	15.2	1.8	14.7	45.1	53.1	66.3
30-35	2.50-2.99	F	19	39.7	11.8	17.0	18.1	41.7	54.1	54.1
30-35	2.50-2.99	Both	42	40.0	13.6	1.8	16.6	44.1	54.0	66.3
36-47	3.00-3.99	M	25	58.7	16.9	8.8	35.3	61.3	81.6	92.2
36-47	3.00-3.99	F	15	50.9	10.9	27.9	32.3	53.5	64.1	64.4
36-47	3.00-3.99	Both	40	55.8	15.3	8.8	33.8	57.7	76.6	92.2
48-59	4.00-4.99	M	23	76.1	16.8	42.2	59.8	71.6	107.0	110.4
48-59	4.00-4.99	F	14	65.4	14.5	34.6	42.7	66.0	84.7	86.6
48-59	4.00-4.99	Both	37	72.1	16.6	34.6	46.1	69.4	102.1	110.4
60-71	5.00-5.99	M	21	100.9	22.0	74.5	81.1	98.0	150.7	153.7
60-71	5.00-5.99	F	15	86.6	18.4	60.3	63.7	86.3	114.9	132.1
60-71	5.00-5.99	Both	36	94.9	21.5	60.3	65.5	89.7	136.8	153.7

2H_Shoulder_Push

Description:	Two-hand maximal push exertion at shoulder height
Configuration:	2H_Bar_Stand
Position:	The vertical position of the 2H bar was set to 77% of measured stature, approximately shoulder height.
Posture:	Standing
Interface:	2H_Bar_Horz
Units:	Newton



2H_Shoulder_Push



2H_Shoulder_Push (N)

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	24	24.2	17.1	3.3	4.2	21.3	53.6	65.0
24-29	2.00-2.49	F	18	29.0	25.8	3.0	4.2	23.7	64.1	109.2
24-29	2.00-2.49	Both	42	26.3	21.1	3.0	4.1	21.3	56.1	109.2
30-35	2.50-2.99	M	24	43.6	21.2	6.2	16.4	38.6	72.9	97.0
30-35	2.50-2.99	F	20	40.1	24.2	2.4	7.4	40.8	73.1	83.5
30-35	2.50-2.99	Both	44	42.0	22.4	2.4	7.9	39.7	73.7	97.0
36-47	3.00-3.99	M	25	86.7	44.9	8.9	14.9	92.7	149.1	179.4
36-47	3.00-3.99	F	15	68.7	28.5	17.4	21.1	69.9	109.2	113.1
36-47	3.00-3.99	Both	40	79.9	40.2	8.9	16.1	79.3	145.7	179.4
48-59	4.00-4.99	M	23	127.7	47.4	43.3	63.1	119.6	187.9	244.0
48-59	4.00-4.99	F	14	108.0	35.0	53.3	57.1	110.0	165.0	171.4
48-59	4.00-4.99	Both	37	120.3	43.7	43.3	58.0	118.7	187.4	244.0
60-71	5.00-5.99	M	21	178.9	41.0	94.6	118.9	175.5	246.9	256.0
60-71	5.00-5.99	F	15	153.2	49.3	78.0	84.9	158.4	220.7	224.0
60-71	5.00-5.99	Both	36	168.2	45.8	78.0	92.9	169.3	229.8	256.0

2H_Shoulder_Up

Description: Two-hand maximal upward exertion at shoulder height

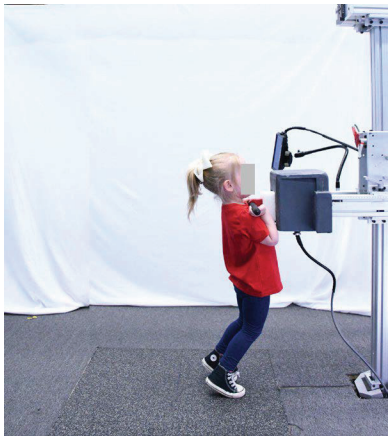
Configuration: 2H_Bar_Stand

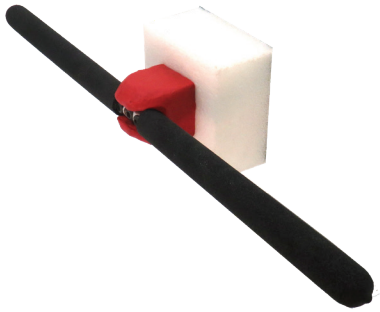
Position: The vertical position of the 2H bar was set to 77% of measured stature, approximately shoulder height.

Posture: Standing

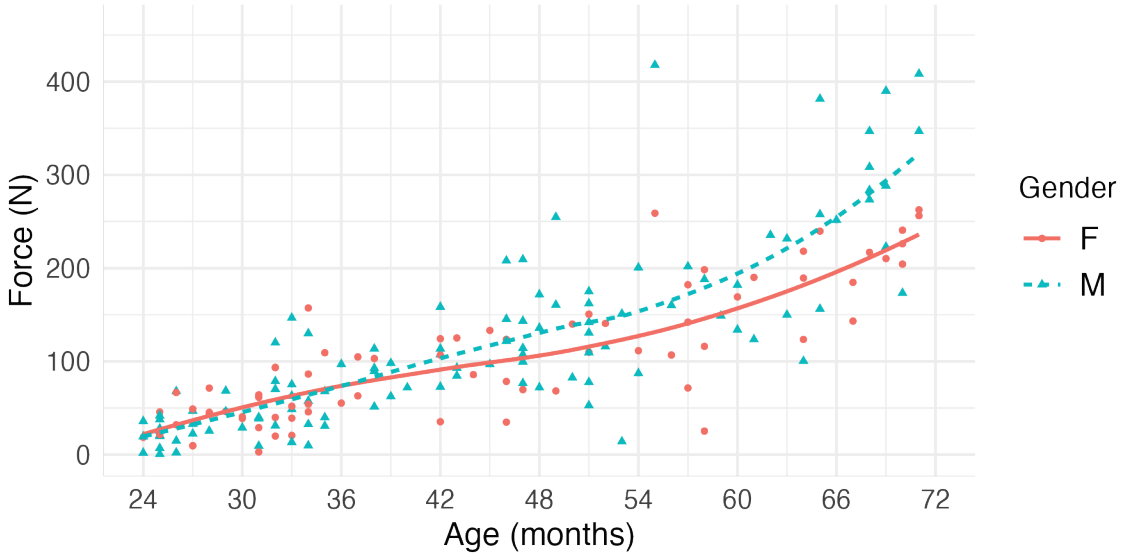
Interface: 2H_Bar_Horz

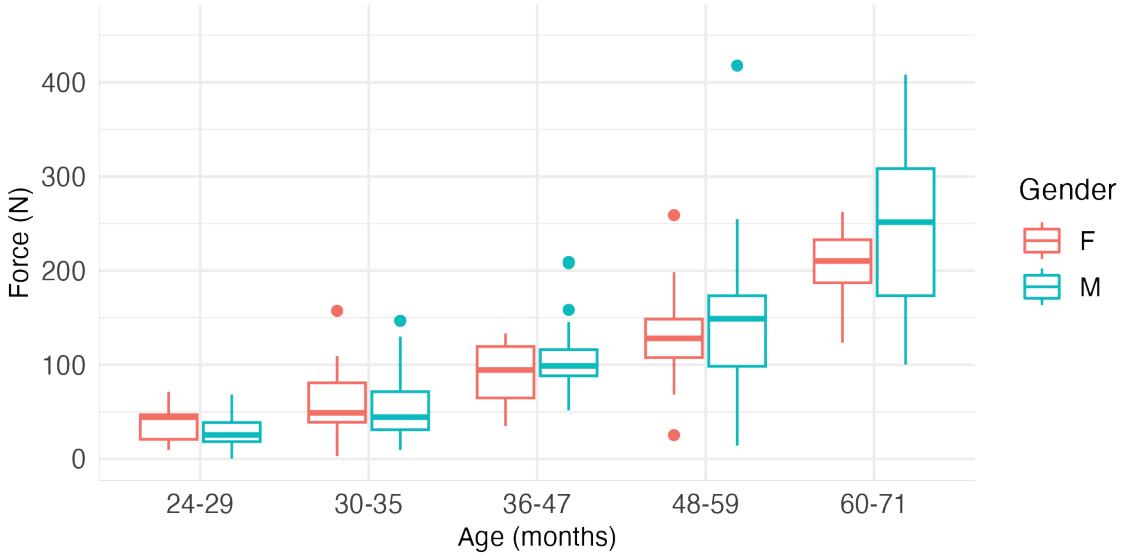
Units: Newton





2H_Shoulder_Up



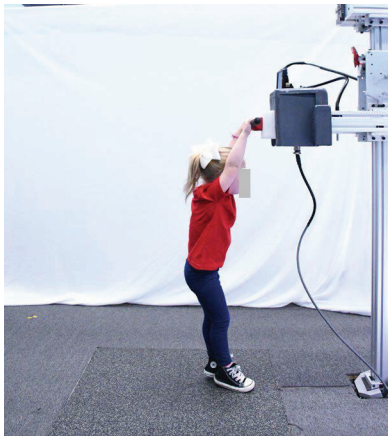


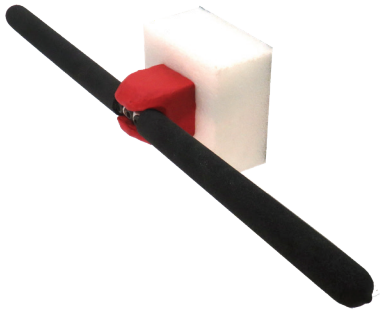
2H_Shoulder_Up (N)

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	20	28.3	19.5	0.5	1.8	25.5	68.0	68.4
24-29	2.00-2.49	F	12	38.2	20.4	9.6	9.6	44.3	68.8	71.4
24-29	2.00-2.49	Both	32	32.0	20.1	0.5	2.1	30.0	68.1	71.4
30-35	2.50-2.99	M	20	56.6	38.8	9.4	9.8	44.4	130.8	146.7
30-35	2.50-2.99	F	18	58.2	37.7	2.9	17.4	48.9	116.5	157.3
30-35	2.50-2.99	Both	38	57.4	37.8	2.9	9.8	47.3	132.5	157.3
36-47	3.00-3.99	M	24	109.5	39.7	51.4	63.9	98.8	200.6	209.2
36-47	3.00-3.99	F	14	88.8	33.5	34.9	35.1	94.5	127.9	133.2
36-47	3.00-3.99	Both	38	101.9	38.4	34.9	49.0	98.8	165.8	209.2
48-59	4.00-4.99	M	23	148.4	80.3	14.0	54.7	148.9	249.4	417.8
48-59	4.00-4.99	F	14	130.2	58.5	25.3	53.3	128.0	219.5	258.9
48-59	4.00-4.99	Both	37	141.5	72.5	14.0	47.3	140.7	255.5	417.8
60-71	5.00-5.99	M	21	249.8	92.1	100.4	123.6	251.5	390.0	408.3
60-71	5.00-5.99	F	15	205.0	39.5	123.5	137.3	210.2	258.1	262.5
60-71	5.00-5.99	Both	36	231.1	77.3	100.4	123.6	224.4	383.6	408.3

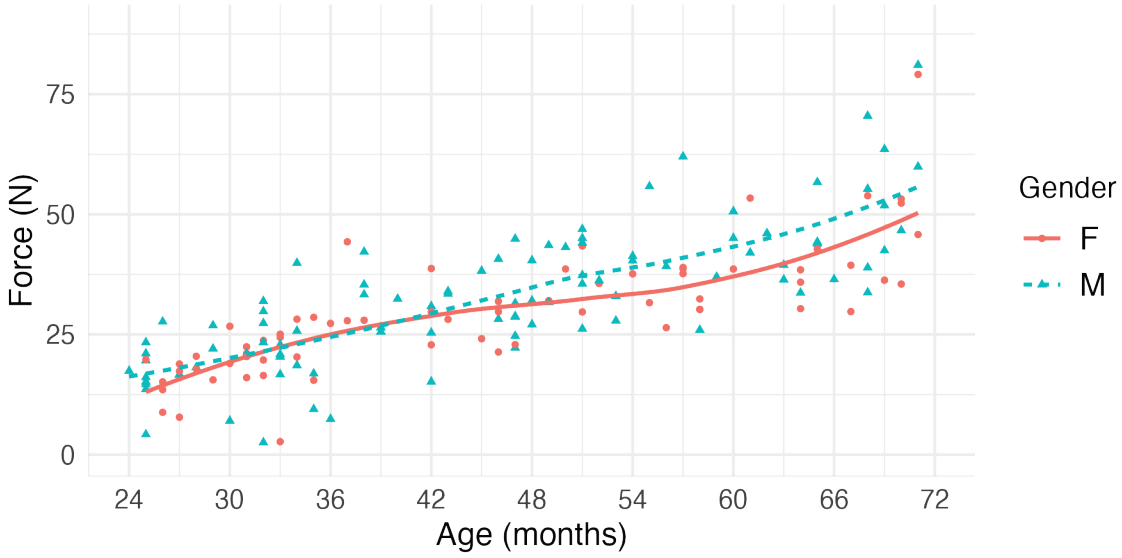
2H_OverHead_Pull

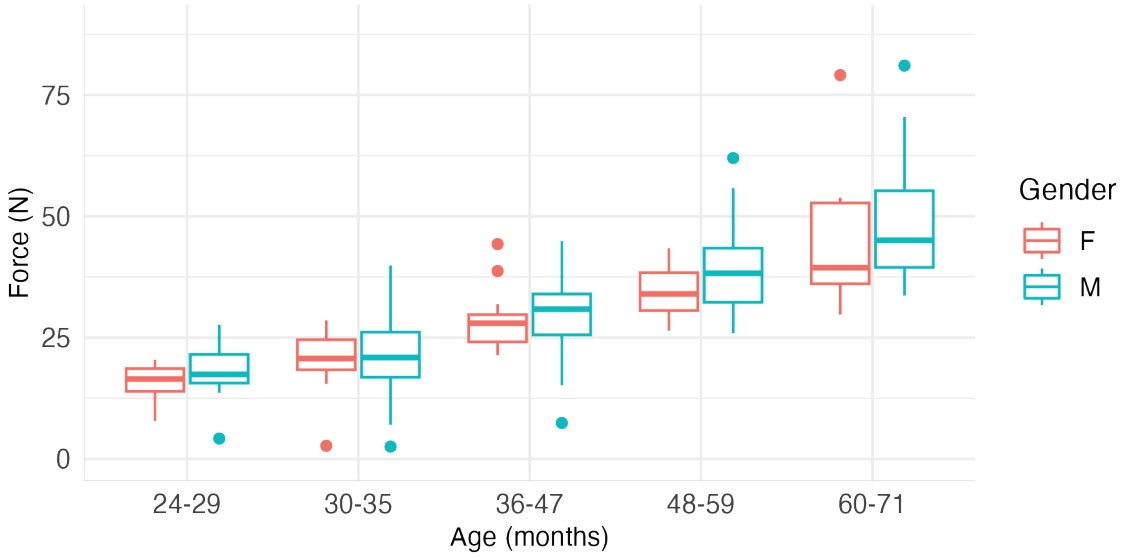
Description:	Two-hand maximal pull exertion at overhead height
Configuration:	2H_Bar_Stand
Position:	The vertical position of the 2H bar was set to 110% of measured stature, approximately overhead height.
Posture:	Standing
Interface:	2H_Bar_Horz
Units:	Newton





2H_OverHead_Pull



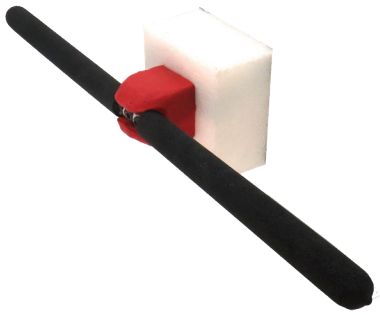


2H_OverHead_Pull (N)

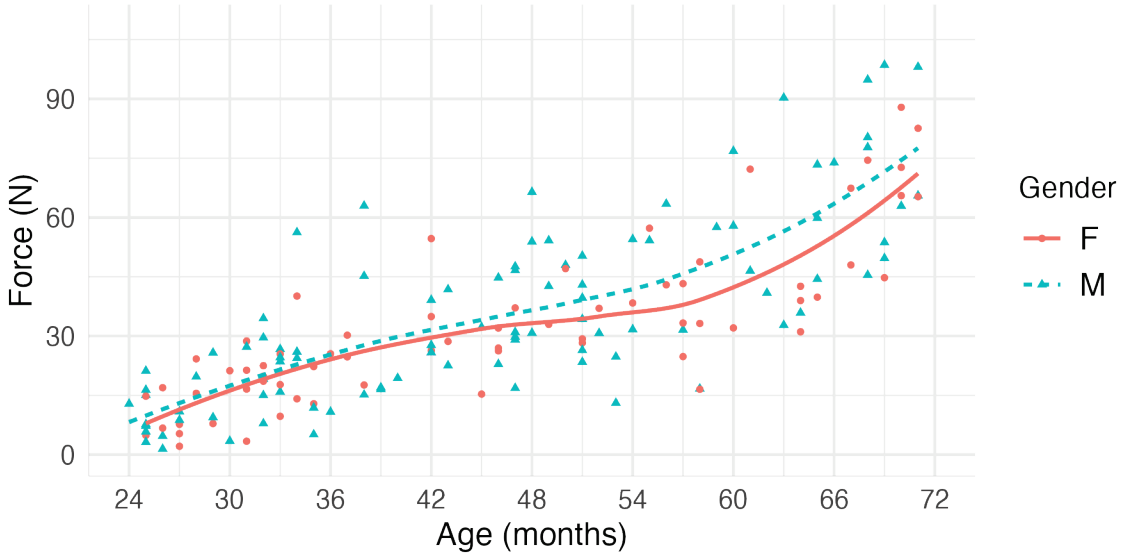
Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	15	18.2	5.8	4.2	10.8	17.4	27.1	27.7
24-29	2.00-2.49	F	10	15.5	4.4	7.8	8.2	16.5	20.2	20.5
24-29	2.00-2.49	Both	25	17.1	5.3	4.2	8.0	17.4	26.2	27.7
30-35	2.50-2.99	M	16	20.9	9.4	2.5	5.9	20.9	33.9	39.9
30-35	2.50-2.99	F	16	20.6	6.3	2.7	12.3	20.7	28.3	28.6
30-35	2.50-2.99	Both	32	20.8	7.9	2.5	5.1	20.9	30.8	39.9
36-47	3.00-3.99	M	21	30.0	8.7	7.4	15.2	30.9	42.2	44.9
36-47	3.00-3.99	F	13	29.0	6.5	21.4	22.2	28.0	40.9	44.3
36-47	3.00-3.99	Both	34	29.6	7.8	7.4	19.2	28.7	42.9	44.9
48-59	4.00-4.99	M	22	38.7	9.1	25.9	26.2	38.3	55.4	62.0
48-59	4.00-4.99	F	14	34.5	4.8	26.4	28.5	34.0	40.5	43.4
48-59	4.00-4.99	Both	36	37.1	7.9	25.9	26.4	37.1	49.1	62.0
60-71	5.00-5.99	M	21	48.5	12.4	33.7	33.7	45.1	70.5	81.1
60-71	5.00-5.99	F	15	44.3	12.6	29.8	30.2	39.4	61.4	79.1
60-71	5.00-5.99	Both	36	46.7	12.5	29.8	32.8	44.1	72.6	81.1

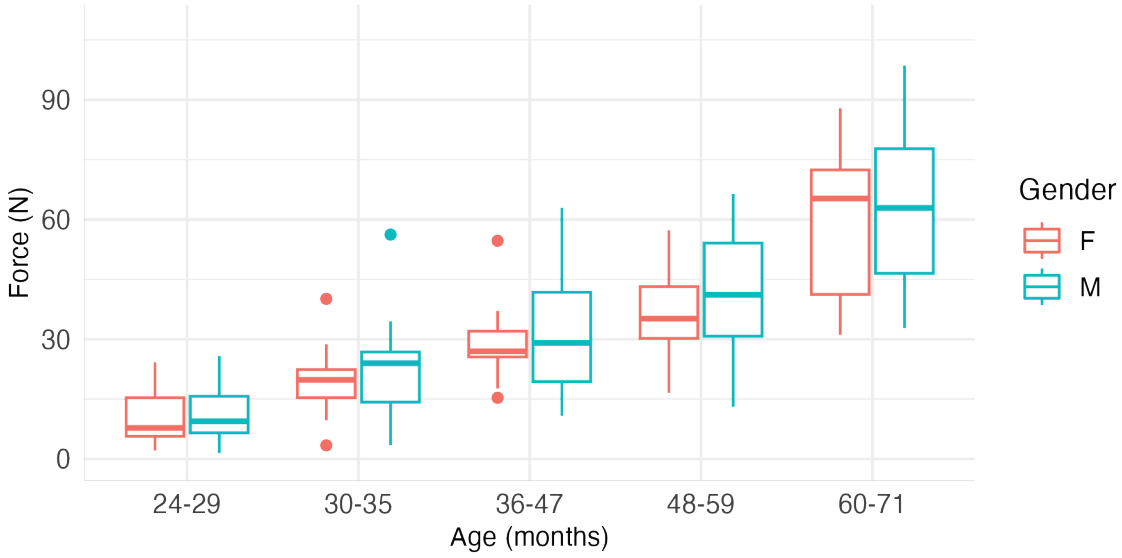
2H_OverHead_Push

Description:	Two-hand maximal push exertion at overhead height
Configuration:	2H_Bar_Stand
Position:	The vertical position of the 2H bar was set to 110% of measured stature, approximately overhead height.
Posture:	Standing
Interface:	2H_Bar_Horz
Units:	Newton



2H_OverHead_Push





2H_OverHead_Push (N)

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	15	11.3	7.1	1.4	2.6	9.4	22.6	25.8
24-29	2.00-2.49	F	10	10.6	6.9	2.1	3.4	7.8	20.9	24.2
24-29	2.00-2.49	Both	25	11.0	6.9	1.4	2.3	8.8	23.6	25.8
30-35	2.50-2.99	M	16	21.9	12.9	3.4	4.7	24.0	39.9	56.2
30-35	2.50-2.99	F	15	19.6	8.5	3.4	7.8	19.8	32.1	40.1
30-35	2.50-2.99	Both	31	20.8	10.9	3.4	4.3	21.2	37.3	56.2
36-47	3.00-3.99	M	21	30.7	13.6	10.8	15.2	29.1	47.6	63.0
36-47	3.00-3.99	F	13	29.3	9.7	15.3	16.7	27.0	44.1	54.7
36-47	3.00-3.99	Both	34	30.2	12.1	10.8	15.3	28.2	50.1	63.0
48-59	4.00-4.99	M	22	40.5	15.2	13.1	17.0	41.1	63.1	66.4
48-59	4.00-4.99	F	14	36.6	10.6	16.5	21.9	35.2	51.7	57.3
48-59	4.00-4.99	Both	36	39.0	13.6	13.1	16.6	37.7	59.0	66.4
60-71	5.00-5.99	M	21	64.7	20.6	32.8	35.9	62.9	98.1	98.6
60-71	5.00-5.99	F	15	57.7	18.9	31.1	31.8	65.3	84.1	87.9
60-71	5.00-5.99	Both	36	61.8	19.9	31.1	32.6	64.1	95.7	98.6

1H_Seated_Pull

Description: One-hand seated lateral pull exertion

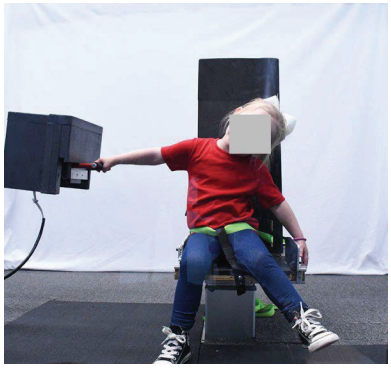
Configuration: 1H_Bar_Seated_Lateral

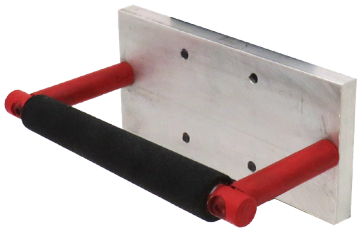
Position: The vertical position of the 1H bar was set to 90% of seated acromion height, approximately chest height. The horizontal position of the 1H bar was set at the lateral reach from centerline, defined by the difference between predicted lateral reach and 50% of predicted biacromial breadth. All measures are predicted from stature.

Posture: Seated

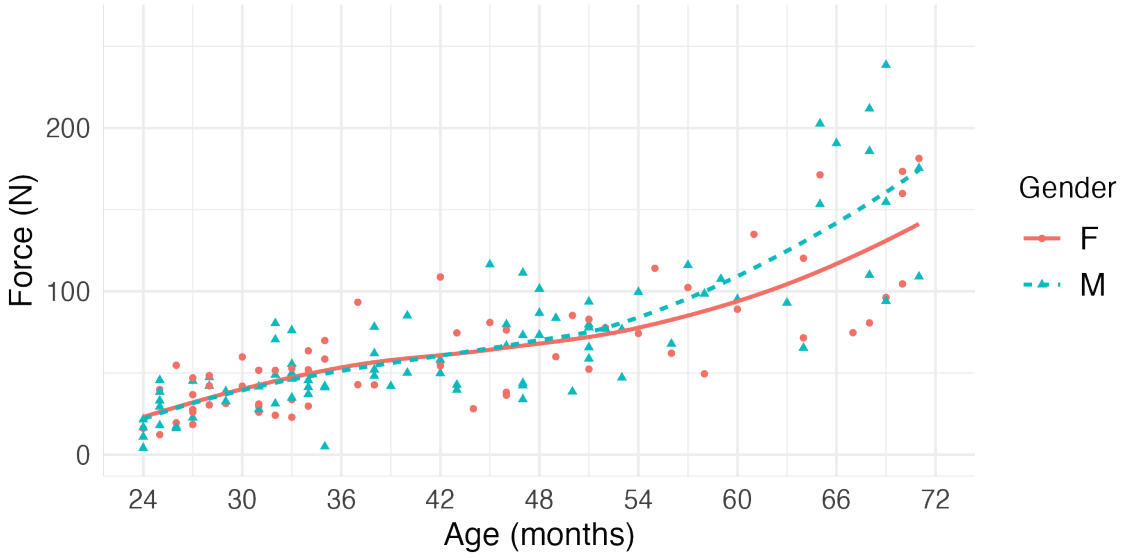
Interface: 1H_Bar_Horz

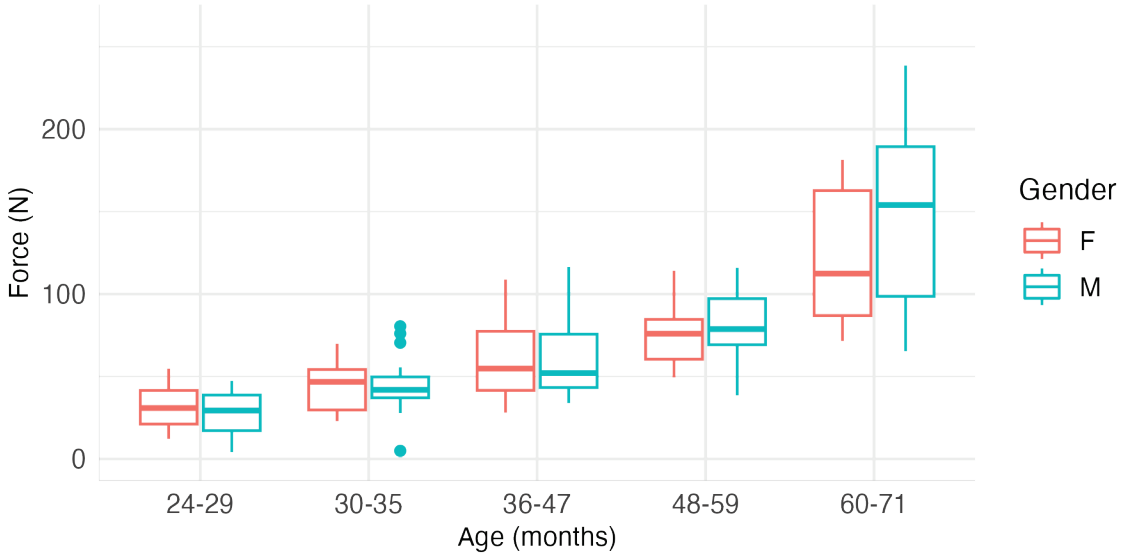
Units: Newton





1H_Seated_Pull





1H_Seated_Pull (N)

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	17	28.2	13.4	4.1	9.6	29.4	46.0	47.3
24-29	2.00-2.49	F	14	32.2	13.1	12.2	14.7	30.9	50.6	54.7
24-29	2.00-2.49	Both	31	30.0	13.2	4.1	11.6	30.4	47.8	54.7
30-35	2.50-2.99	M	17	45.6	18.2	4.9	23.2	41.9	76.9	80.5
30-35	2.50-2.99	F	16	43.7	15.5	22.9	23.8	46.7	65.1	69.8
30-35	2.50-2.99	Both	33	44.7	16.7	4.9	23.6	41.9	72.7	80.5
36-47	3.00-3.99	M	19	61.8	23.6	33.9	39.1	52.1	111.8	116.4
36-47	3.00-3.99	F	12	61.0	25.4	28.1	32.7	54.8	100.3	108.8
36-47	3.00-3.99	Both	31	61.5	23.9	28.1	35.1	54.4	110.1	116.4
48-59	4.00-4.99	M	18	80.5	20.5	38.6	45.9	78.7	108.8	116.0
48-59	4.00-4.99	F	10	76.0	21.1	49.5	50.8	75.9	108.8	114.1
48-59	4.00-4.99	Both	28	78.9	20.4	38.6	48.0	77.8	111.8	116.0
60-71	5.00-5.99	M	14	148.5	54.0	65.3	83.3	154.0	221.2	238.5
60-71	5.00-5.99	F	12	121.5	41.3	71.5	73.3	112.4	177.0	181.4
60-71	5.00-5.99	Both	26	136.0	49.5	65.3	72.3	127.6	209.5	238.5

1H_Seated_Push

Description: One-hand seated lateral push exertion

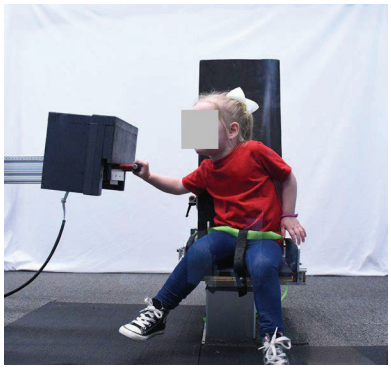
Configuration: 1H_Bar_Seated_Lateral

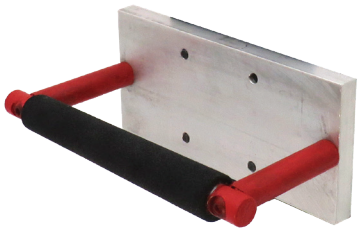
Position: The vertical position of the 1H bar was set to 90% of seated acromion height, approximately chest height. The horizontal position of the 1H bar was set at 70% of the lateral reach from centerline, defined by the difference between predicted lateral reach and 50% of predicted biacromial breadth. All measures are predicted from stature.

Posture: Seated

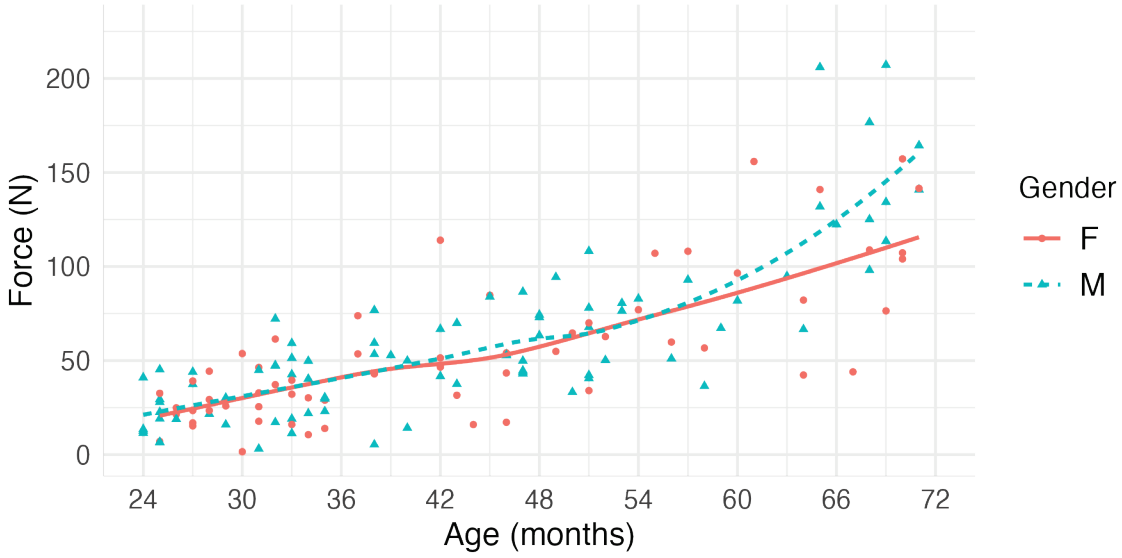
Interface: 1H_Bar_Horz

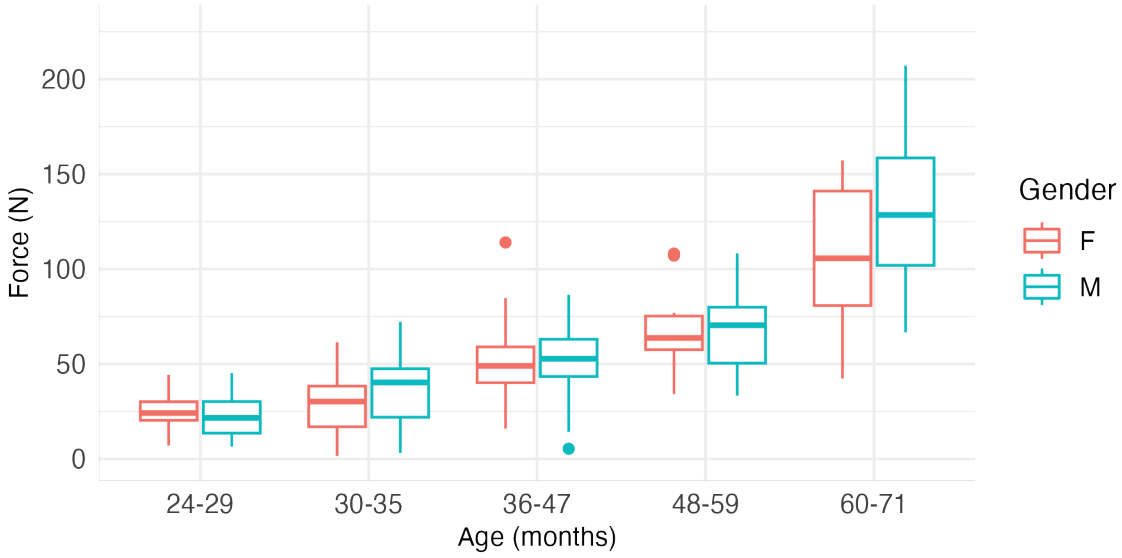
Units: Newton





1H_Seated_Push





1H_Seated_Push (N)

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	17	23.8	12.6	6.5	6.6	21.6	44.3	45.3
24-29	2.00-2.49	F	12	25.3	10.2	7.0	11.6	24.2	41.5	44.3
24-29	2.00-2.49	Both	29	24.4	11.5	6.5	6.8	23.4	44.2	45.3
30-35	2.50-2.99	M	17	35.9	18.4	3.1	9.7	40.3	61.9	72.3
30-35	2.50-2.99	F	15	29.9	16.4	1.6	7.9	30.2	56.1	61.5
30-35	2.50-2.99	Both	32	33.1	17.5	1.6	7.3	31.3	60.2	72.3
36-47	3.00-3.99	M	19	51.9	20.5	5.4	13.3	52.8	84.2	86.6
36-47	3.00-3.99	F	12	52.4	27.8	16.0	16.7	49.0	97.9	114.0
36-47	3.00-3.99	Both	31	52.1	23.1	5.4	15.1	51.4	85.7	114.0
48-59	4.00-4.99	M	18	67.4	21.4	33.2	36.0	70.4	96.5	108.2
48-59	4.00-4.99	F	10	69.5	23.0	34.1	43.4	63.7	107.6	108.1
48-59	4.00-4.99	Both	28	68.2	21.6	33.2	34.9	67.6	107.8	108.2
60-71	5.00-5.99	M	14	133.1	43.0	66.6	76.5	128.5	206.4	207.1
60-71	5.00-5.99	F	12	104.8	39.3	42.3	43.3	105.7	156.5	157.2
60-71	5.00-5.99	Both	26	120.0	43.0	42.3	49.7	117.9	198.6	207.1

1H_Seated_Down

Description: One-hand seated lateral downward exertion

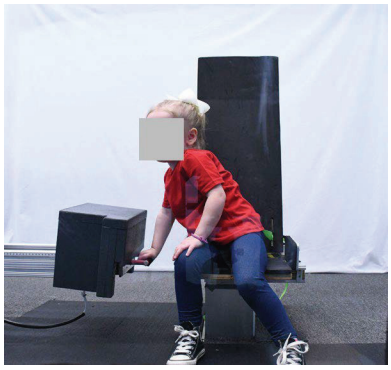
Configuration: 1H_Bar_Seated_Lateral

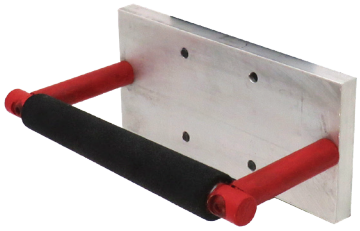
Position: The vertical position of the 1H bar was set to be 2" above the foam on the test seat. The horizontal position of the 1H bar was set laterally 245 mm from centerline.

Posture: Seated

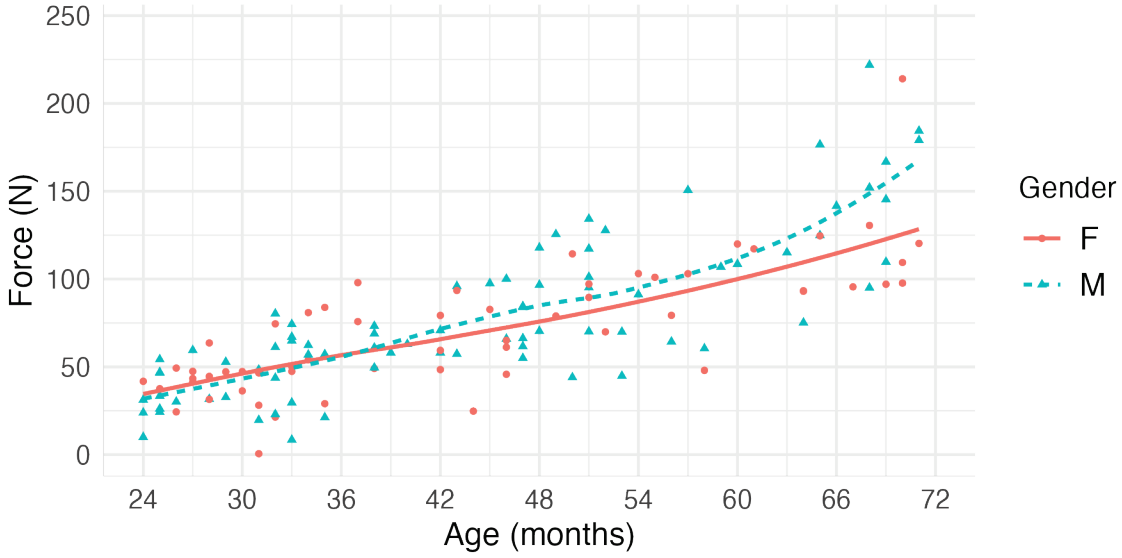
Interface: 1H_Bar_Horz

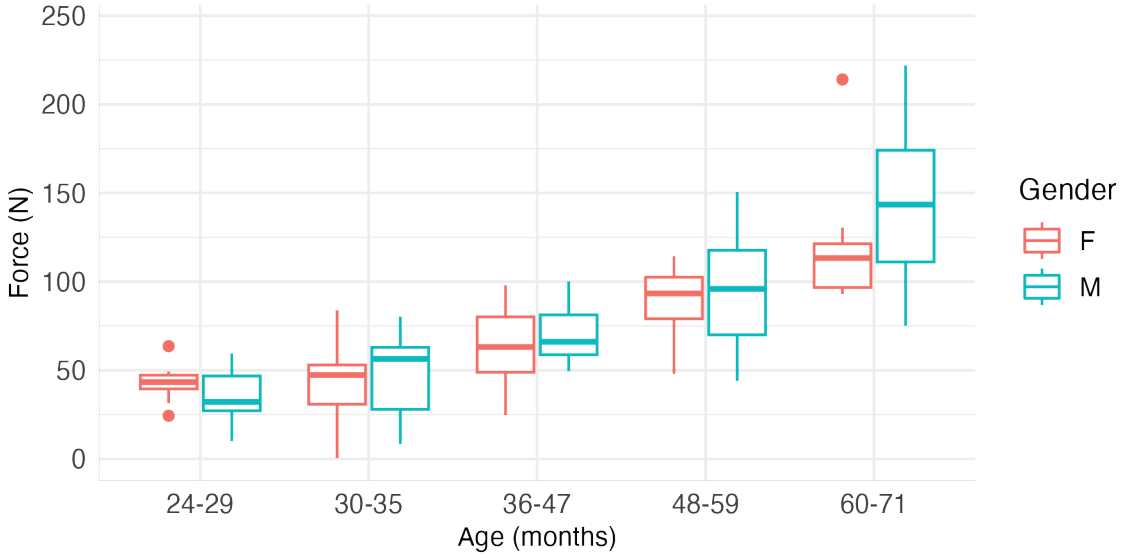
Units: Newton





1H_Seated_Down





1H_Seated_Down (N)

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	14	35.9	14.0	10.0	19.0	32.2	56.1	59.5
24-29	2.00-2.49	F	11	42.9	10.1	24.3	27.9	43.4	56.4	63.6
24-29	2.00-2.49	Both	25	39.0	12.7	10.0	24.0	41.3	58.4	63.6
30-35	2.50-2.99	M	16	48.4	21.7	8.5	16.9	56.4	75.8	80.3
30-35	2.50-2.99	F	14	46.2	23.1	0.6	14.1	47.3	81.9	83.9
30-35	2.50-2.99	Both	30	47.4	22.0	0.6	13.5	47.9	80.6	83.9
36-47	3.00-3.99	M	18	70.6	15.5	49.5	54.2	66.1	97.9	100.1
36-47	3.00-3.99	F	12	65.2	21.5	24.8	36.3	63.1	95.5	97.9
36-47	3.00-3.99	Both	30	68.4	18.0	24.8	47.0	65.5	97.7	100.1
48-59	4.00-4.99	M	18	93.8	31.6	44.0	44.7	95.9	136.7	150.6
48-59	4.00-4.99	F	10	88.4	19.7	48.0	57.9	93.3	109.3	114.3
48-59	4.00-4.99	Both	28	91.9	27.6	44.0	45.9	95.9	132.0	150.6
60-71	5.00-5.99	M	14	142.6	40.5	75.2	88.1	143.5	197.5	221.9
60-71	5.00-5.99	F	12	117.7	33.2	93.1	93.2	113.3	168.1	214.0
60-71	5.00-5.99	Both	26	131.1	38.7	75.2	93.1	120.1	206.6	221.9

1H_Seated_Up

Description: One-hand seated lateral upward exertion

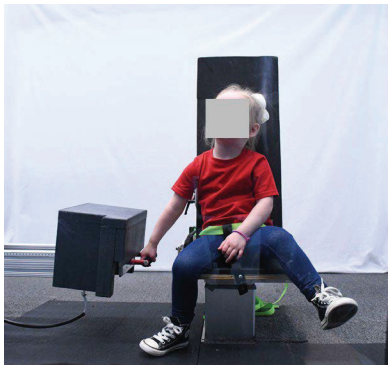
Configuration: 1H_Bar_Seated_Lateral

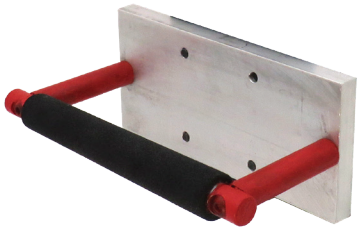
Position: The vertical position of the 1H bar was set to be 2" above the foam on the test seat. The horizontal position of the 1H bar was set laterally 245 mm from centerline.

Posture: Seated

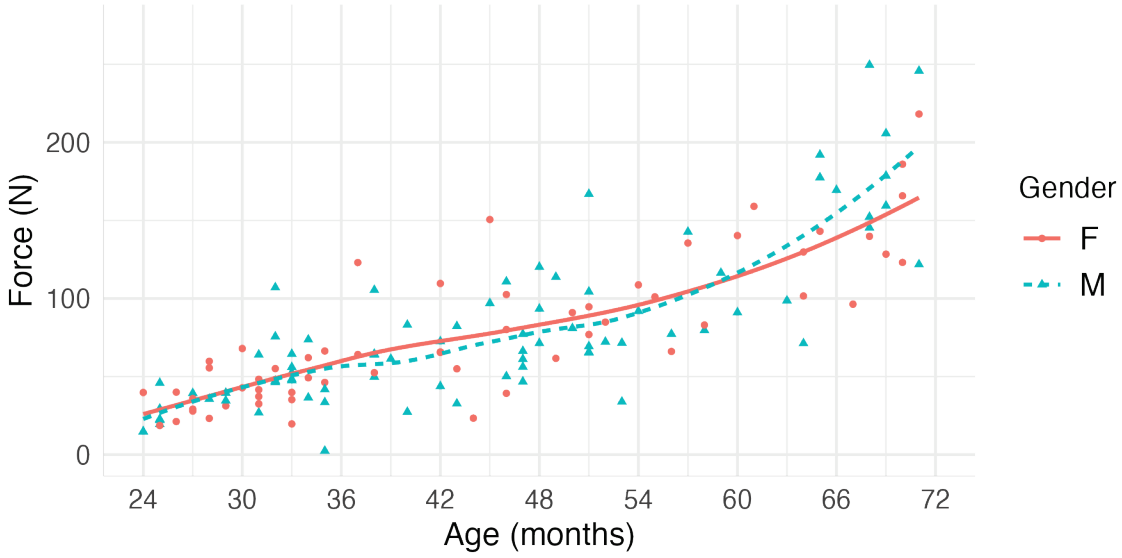
Interface: 1H_Bar_Horz

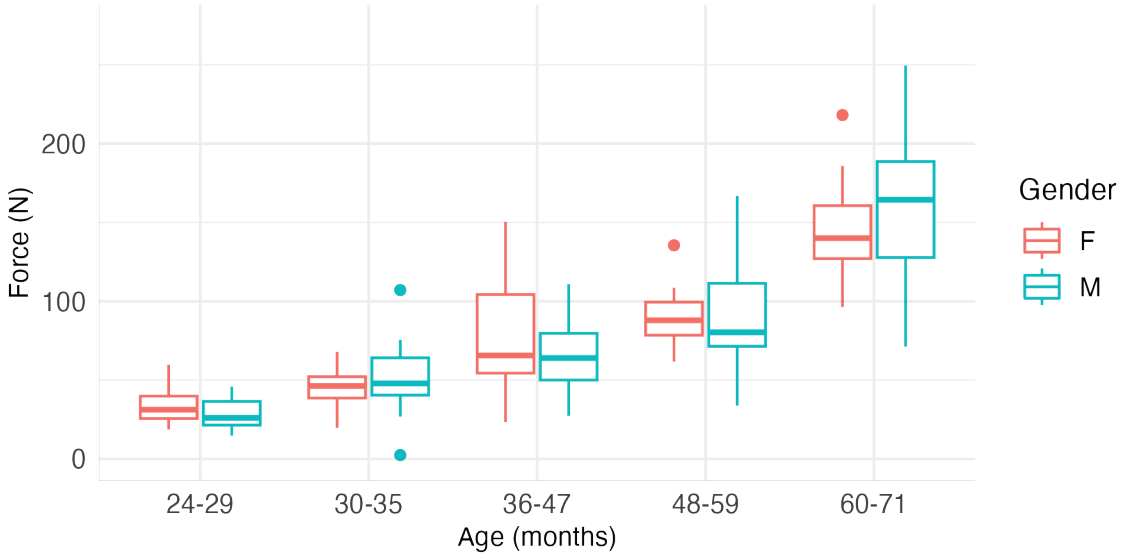
Units: Newton





1H_Seated_Up


Force (N)
200
100
0
24
30
36
42
48
54
60
66
72
Age (months)
Gender
F
M


Force (N)
200
100
0
24-29
30-35
36-47
48-59
60-71
Age (months)
Gender
F
M

1H_Seated_Up (N)

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	12	28.4	10.5	14.8	14.8	26.1	42.4	45.9
24-29	2.00-2.49	F	11	34.8	13.3	18.7	19.9	31.3	57.7	59.8
24-29	2.00-2.49	Both	23	31.4	12.1	14.8	15.2	29.4	54.6	59.8
30-35	2.50-2.99	M	16	51.5	23.4	2.4	20.8	47.9	83.5	107.1
30-35	2.50-2.99	F	15	46.2	13.1	19.7	28.7	46.3	66.9	68.0
30-35	2.50-2.99	Both	31	48.9	19.0	2.4	23.3	47.5	74.7	107.1
36-47	3.00-3.99	M	19	65.9	22.8	27.3	32.2	64.0	106.0	110.9
36-47	3.00-3.99	F	12	77.6	37.0	23.4	32.1	65.6	135.4	150.6
36-47	3.00-3.99	Both	31	70.4	29.1	23.4	30.0	64.6	116.9	150.6
48-59	4.00-4.99	M	18	91.0	31.8	33.9	60.6	80.3	146.3	166.9
48-59	4.00-4.99	F	10	90.4	21.6	61.7	63.7	87.9	123.5	135.5
48-59	4.00-4.99	Both	28	90.7	28.1	33.9	63.0	84.0	140.2	166.9
60-71	5.00-5.99	M	14	161.3	53.6	71.3	84.1	164.4	247.1	249.5
60-71	5.00-5.99	F	12	144.3	34.3	96.3	99.2	140.1	200.5	218.1
60-71	5.00-5.99	Both	26	153.5	45.7	71.3	92.4	148.8	238.9	249.5

2H_Seated_Pull

Description: Two-hand seated pull exertion

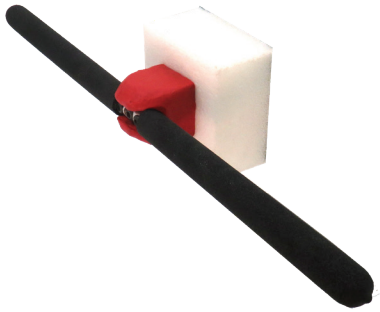
Configuration: 2H_Bar_Seated_Horizontal

Position: The vertical position of the 2H bar was set to 90% of predicted seated acromion height, approximately chest height. The horizontal position of the 2H bar was set at maximum forward reach. All measures are predicted from stature.

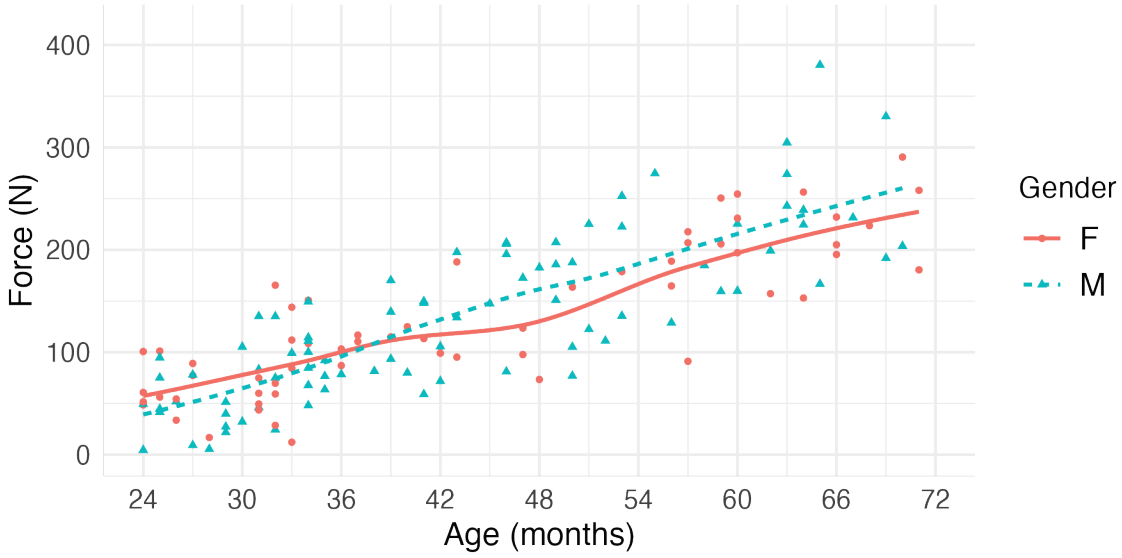
Posture: Seated

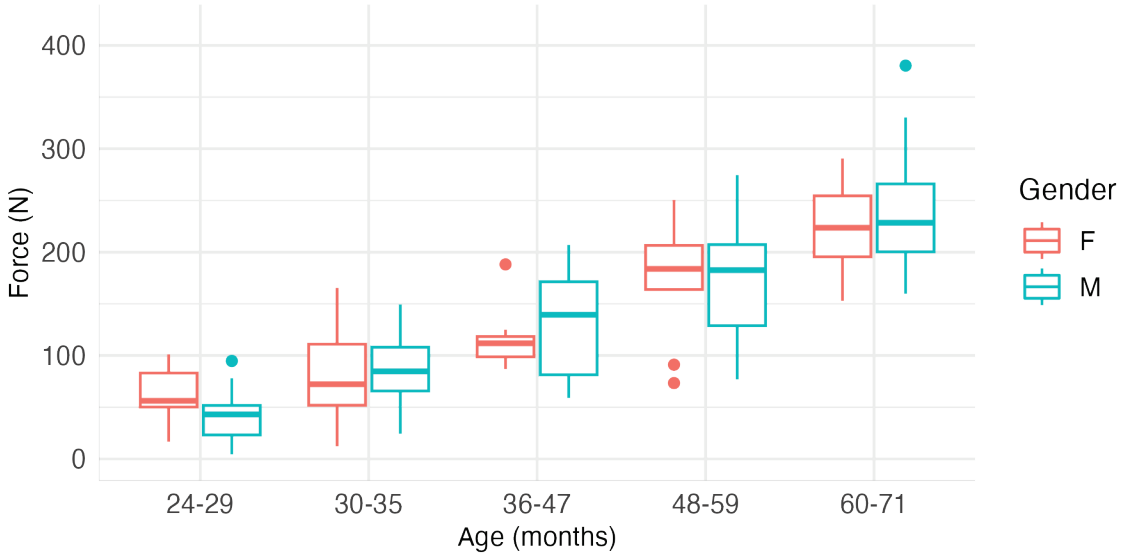
Interface: 2H_Bar_Horz

Units: Newton



2H_Seated_Pull





2H_Seated_Pull (N)

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	14	42.5	27.6	4.5	5.1	43.1	83.9	94.7
24-29	2.00-2.49	F	11	62.7	26.9	16.7	25.2	56.2	100.9	101.2
24-29	2.00-2.49	Both	25	51.4	28.6	4.5	6.2	51.5	99.5	101.2
30-35	2.50-2.99	M	19	86.5	34.8	24.4	31.4	84.7	136.5	149.3
30-35	2.50-2.99	F	14	83.0	46.9	12.1	22.9	72.3	155.9	165.4
30-35	2.50-2.99	Both	33	85.0	39.7	12.1	27.0	83.2	149.9	165.4
36-47	3.00-3.99	M	19	132.5	50.1	59.0	70.5	139.4	205.8	207.0
36-47	3.00-3.99	F	12	114.5	26.0	87.0	91.5	111.9	153.4	188.2
36-47	3.00-3.99	Both	31	125.6	42.8	59.0	75.1	115.0	201.6	207.0
48-59	4.00-4.99	M	17	171.4	54.6	77.0	99.5	182.6	256.9	274.6
48-59	4.00-4.99	F	10	174.1	55.1	73.4	81.4	183.8	235.7	250.6
48-59	4.00-4.99	Both	27	172.4	53.7	73.4	81.2	182.6	251.9	274.6
60-71	5.00-5.99	M	14	241.0	62.5	159.8	164.3	228.4	347.8	380.4
60-71	5.00-5.99	F	13	218.0	41.4	152.9	155.5	223.6	271.1	290.5
60-71	5.00-5.99	Both	27	229.9	53.7	152.9	158.0	225.4	322.6	380.4

2H_Seated_Push

Description: Two-hand seated push exertion

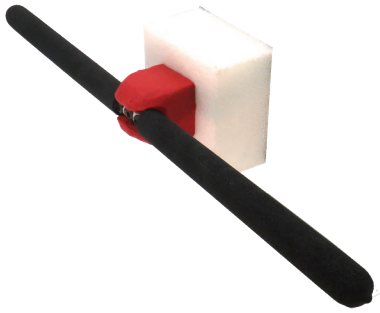
Configuration: 2H_Bar_Seated_Horizontal

Position: The vertical position of the 2H bar was set to 90% of predicted seated acromion height, approximately chest height. The horizontal position of the 2H bar was set at 70% of maximum forward reach. All measures are predicted from stature. The vertical position of the footpush interface was set to align the lowest edge with the height of the seat. The horizontal position of the footpush interface was set relative to the bight on the test seat, to 110% of the difference between measured stature and predicted erect seated height.

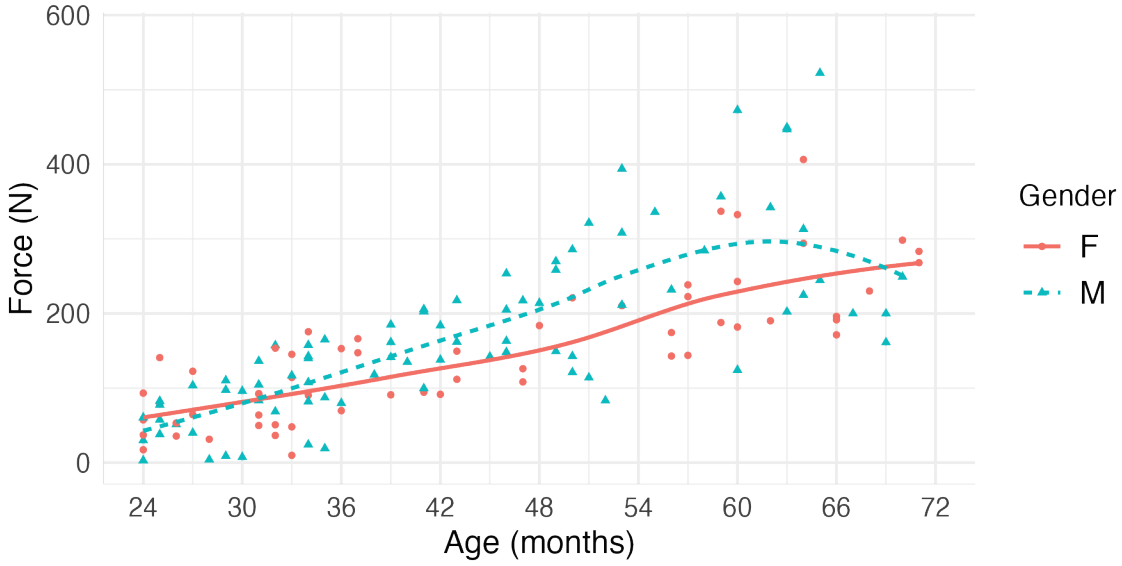
Posture: Seated

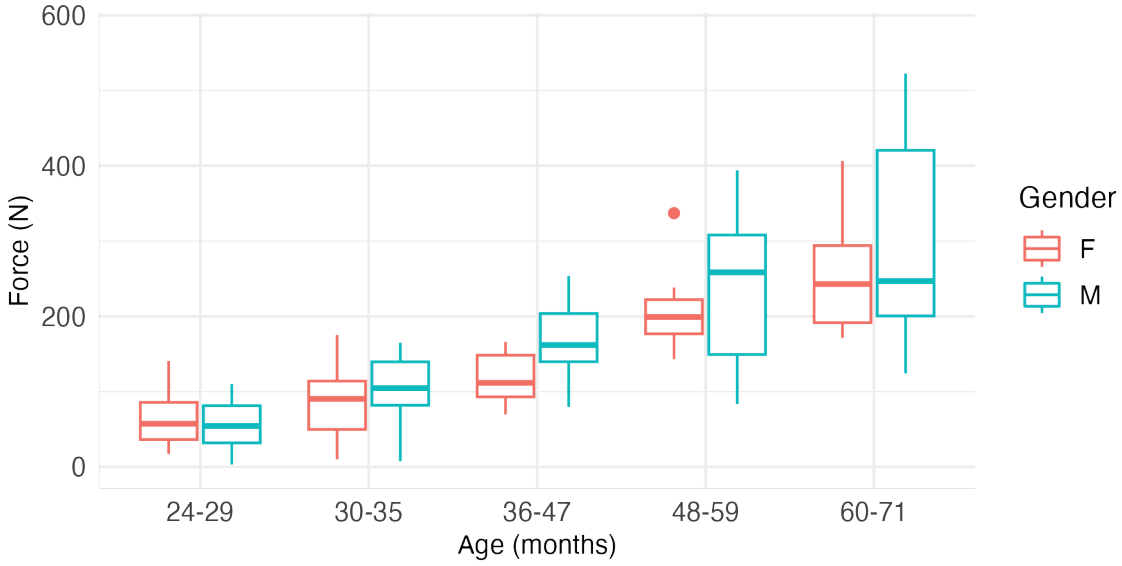
Interface: 2H_Bar_Horz

Units: Newton



2H_Seated_Push





2H_Seated_Push (N)

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	14	54.6	36.3	2.9	3.7	54.4	105.8	110.3
24-29	2.00-2.49	F	11	66.5	39.1	17.3	24.3	57.4	131.7	140.8
24-29	2.00-2.49	Both	25	59.8	37.2	2.9	5.1	57.4	120.1	140.8
30-35	2.50-2.99	M	17	99.8	49.1	7.4	16.8	104.6	159.1	165.1
30-35	2.50-2.99	F	13	86.3	49.8	9.8	25.8	90.4	162.3	175.6
30-35	2.50-2.99	Both	30	93.9	49.0	7.4	14.0	92.4	161.7	175.6
36-47	3.00-3.99	M	19	166.3	44.4	79.8	97.7	161.9	221.2	253.6
36-47	3.00-3.99	F	11	119.0	31.5	69.7	80.3	111.7	159.6	166.2
36-47	3.00-3.99	Both	30	148.9	45.9	69.7	84.8	147.8	217.5	253.6
48-59	4.00-4.99	M	17	240.2	92.5	83.4	107.9	258.4	364.3	394.0
48-59	4.00-4.99	F	10	206.2	56.2	142.9	143.4	199.2	292.6	337.0
48-59	4.00-4.99	Both	27	227.6	81.5	83.4	116.2	221.0	350.9	394.0
60-71	5.00-5.99	M	14	296.6	128.9	124.1	148.2	246.8	490.0	522.4
60-71	5.00-5.99	F	13	252.8	69.6	171.4	177.7	242.9	362.2	406.5
60-71	5.00-5.99	Both	27	275.5	105.1	124.1	164.3	244.5	465.6	522.4

2F_Seated_Push

Description: Two-foot seated push exertion

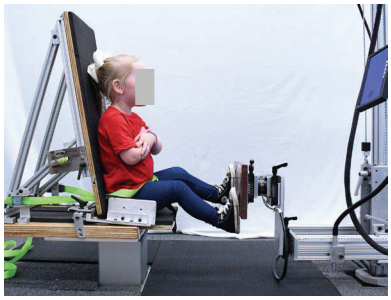
Configuration: 2H_Bar_Seated_Horizontal

Position: The vertical position of the footpush interface was set to align the lowest edge with the height of the seat. The horizontal position of the footpush interface was set relative to the bight on the test seat, to 110% of the difference between measured stature and predicted erect seated height.

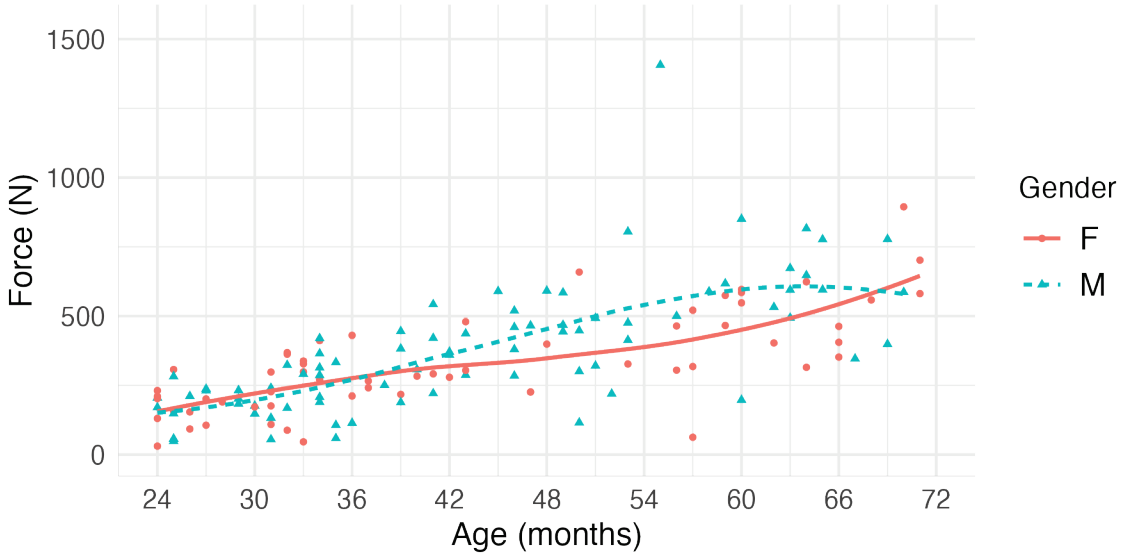
Posture: Seated

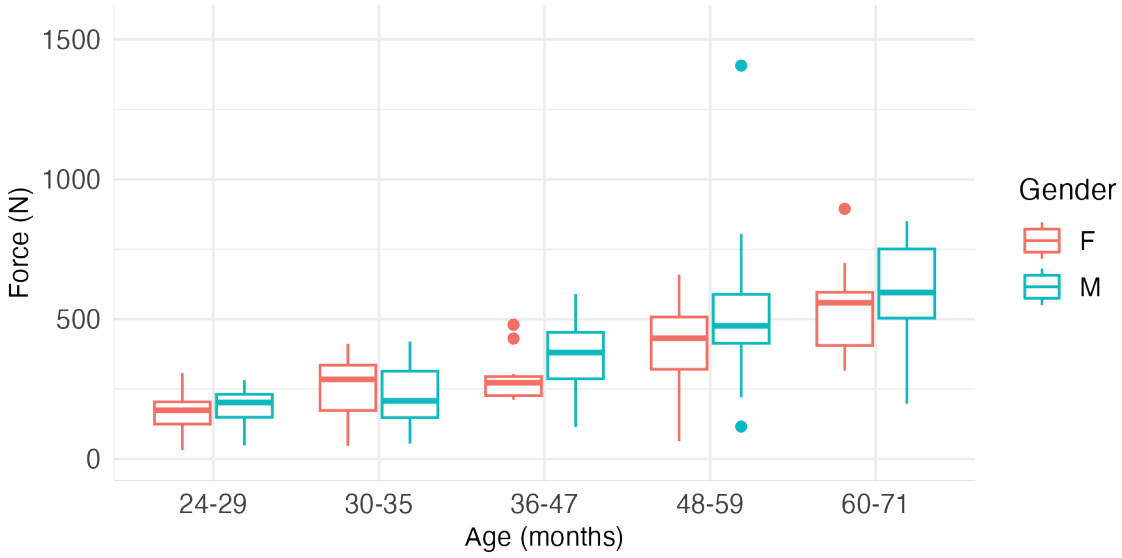
Interface: FootBoard

Units: Newton



2F_Seated_Push





2F_Seated_Push (N)

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	13	174.3	76.0	48.6	53.3	201.9	255.2	282.2
24-29	2.00-2.49	F	12	168.0	72.6	30.8	64.9	174.0	265.5	307.4
24-29	2.00-2.49	Both	25	171.3	72.9	30.8	50.1	190.3	273.2	307.4
30-35	2.50-2.99	M	17	224.5	108.3	54.9	58.3	207.7	376.0	420.2
30-35	2.50-2.99	F	14	249.7	114.8	46.3	73.5	284.5	383.6	411.8
30-35	2.50-2.99	Both	31	235.9	110.1	46.3	57.0	240.5	390.1	420.2
36-47	3.00-3.99	M	19	370.0	125.5	114.2	181.0	380.3	547.3	589.9
36-47	3.00-3.99	F	12	288.2	84.5	211.7	214.9	272.6	452.8	479.8
36-47	3.00-3.99	Both	31	338.3	117.1	114.2	200.0	304.5	531.0	589.9
48-59	4.00-4.99	M	17	517.2	280.6	115.7	198.9	475.9	925.3	1,406.5
48-59	4.00-4.99	F	10	409.8	168.2	62.8	171.9	431.7	621.2	659.1
48-59	4.00-4.99	Both	27	477.4	247.1	62.8	146.9	466.3	761.3	1,406.5
60-71	5.00-5.99	M	14	592.0	188.5	197.3	294.3	595.0	828.4	850.7
60-71	5.00-5.99	F	13	540.7	156.7	315.2	337.4	558.3	779.0	894.6
60-71	5.00-5.99	Both	27	567.3	172.6	197.3	324.6	585.3	840.4	894.6

Dynamometer_24mm_Elbow_Grip

Description: One-hand maximal grip exertion

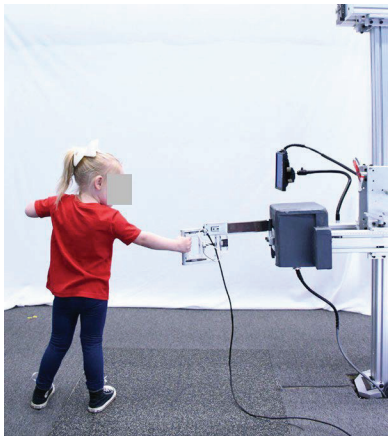
Configuration: Elbow_Stand

Position: The vertical position of the dynamometer was set to 63% of measured stature, approximately elbow height.

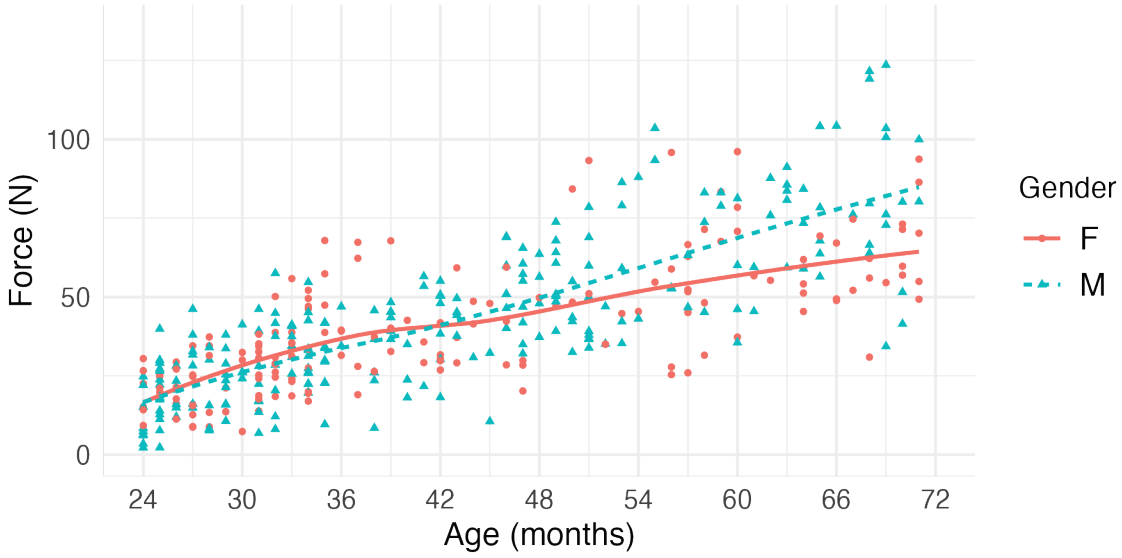
Posture: Standing

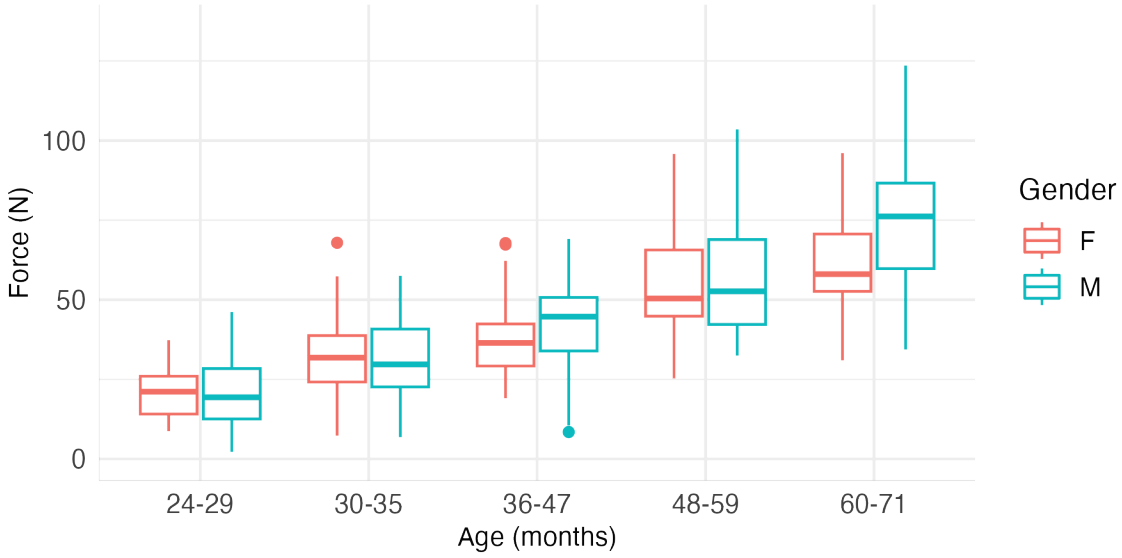
Interface: Dynamometer_24

Units: Newton



Dynamometer_24mm_Elbow_Grip





Dynamometer_24mm_Elbow_Grip (N)

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	52	20.3	10.6	2.2	4.9	19.4	38.0	46.2
24-29	2.00-2.49	F	32	20.8	8.2	8.7	8.9	21.1	34.5	37.3
24-29	2.00-2.49	Both	84	20.5	9.7	2.2	6.5	20.8	36.9	46.2
30-35	2.50-2.99	M	48	30.4	11.6	6.8	10.5	29.7	45.8	57.5
30-35	2.50-2.99	F	44	32.8	12.8	7.3	17.1	31.8	55.3	67.9
30-35	2.50-2.99	Both	92	31.6	12.2	6.8	12.9	30.9	53.3	67.9
36-47	3.00-3.99	M	48	41.9	14.2	8.4	18.1	44.7	63.8	69.2
36-47	3.00-3.99	F	32	38.5	13.0	19.0	23.6	36.4	64.5	67.8
36-47	3.00-3.99	Both	80	40.5	13.7	8.4	19.0	39.8	65.6	69.2
48-59	4.00-4.99	M	45	57.0	18.4	32.5	35.2	52.6	87.6	103.5
48-59	4.00-4.99	F	26	54.0	19.7	25.4	26.4	50.4	91.0	95.8
48-59	4.00-4.99	Both	71	55.9	18.8	25.4	32.0	51.0	90.6	103.5
60-71	5.00-5.99	M	39	76.3	22.6	34.3	40.9	76.2	119.4	123.5
60-71	5.00-5.99	F	30	61.6	15.0	30.9	40.9	58.0	90.4	96.1
60-71	5.00-5.99	Both	69	69.9	20.8	30.9	39.0	67.8	104.2	123.5

FingerSurface_Index_Elbow_Push

Description: Index finger pad maximal push exertion at elbow height

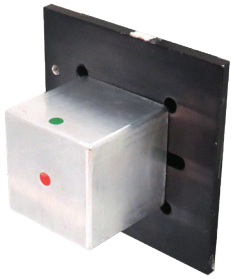
Configuration: Elbow_Stand

Position: The vertical position of the finger surface was set to 63% of measured stature, approximately elbow height.

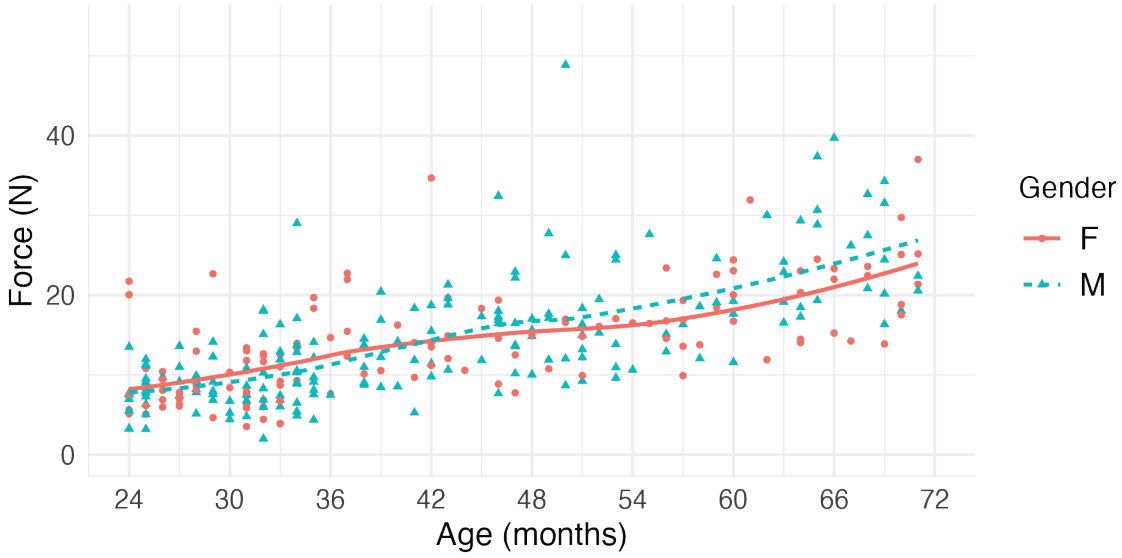
Posture: Standing

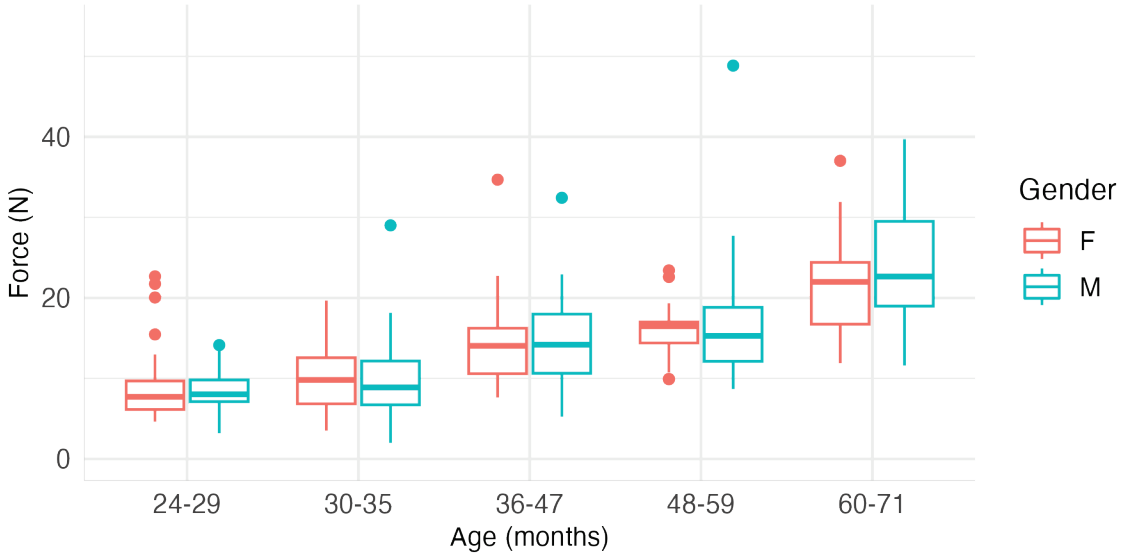
Interface: FingerSurface

Units: Newton



FingerSurface_Index_Elbow_Push





FingerSurface_Index_Elbow_Push (N)

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	35	8.5	2.8	3.2	3.3	8.0	13.5	14.1
24-29	2.00-2.49	F	28	9.2	4.9	4.6	5.1	7.7	21.2	22.7
24-29	2.00-2.49	Both	63	8.8	3.9	3.2	4.7	7.8	15.3	22.7
30-35	2.50-2.99	M	41	9.9	5.0	2.0	4.4	8.9	18.0	29.0
30-35	2.50-2.99	F	32	9.9	4.0	3.5	3.9	9.8	15.9	19.7
30-35	2.50-2.99	Both	73	9.9	4.6	2.0	4.2	9.1	18.1	29.0
36-47	3.00-3.99	M	37	14.7	5.5	5.3	7.6	14.2	22.3	32.4
36-47	3.00-3.99	F	25	14.7	5.9	7.6	8.0	14.0	22.6	34.7
36-47	3.00-3.99	Both	62	14.7	5.6	5.3	7.7	14.1	22.7	34.7
48-59	4.00-4.99	M	35	17.2	7.6	8.7	9.5	15.3	27.7	48.8
48-59	4.00-4.99	F	20	16.0	3.5	9.9	9.9	16.5	22.6	23.4
48-59	4.00-4.99	Both	55	16.7	6.4	8.7	9.8	16.1	25.8	48.8
60-71	5.00-5.99	M	28	24.2	7.0	11.6	16.4	22.7	36.3	39.7
60-71	5.00-5.99	F	25	21.4	6.0	11.9	13.9	22.0	31.5	37.0
60-71	5.00-5.99	Both	53	22.9	6.7	11.6	14.0	22.4	35.4	39.7

FingerSurface_Thumb_Elbow_Push

Description: Thumb pad maximal push exertion at elbow height

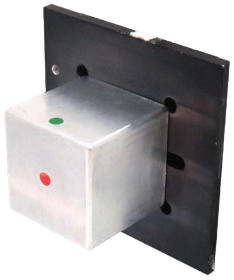
Configuration: Elbow_Stand

Position: The vertical position of the finger surface was set to 63% of measured stature, approximately elbow height.

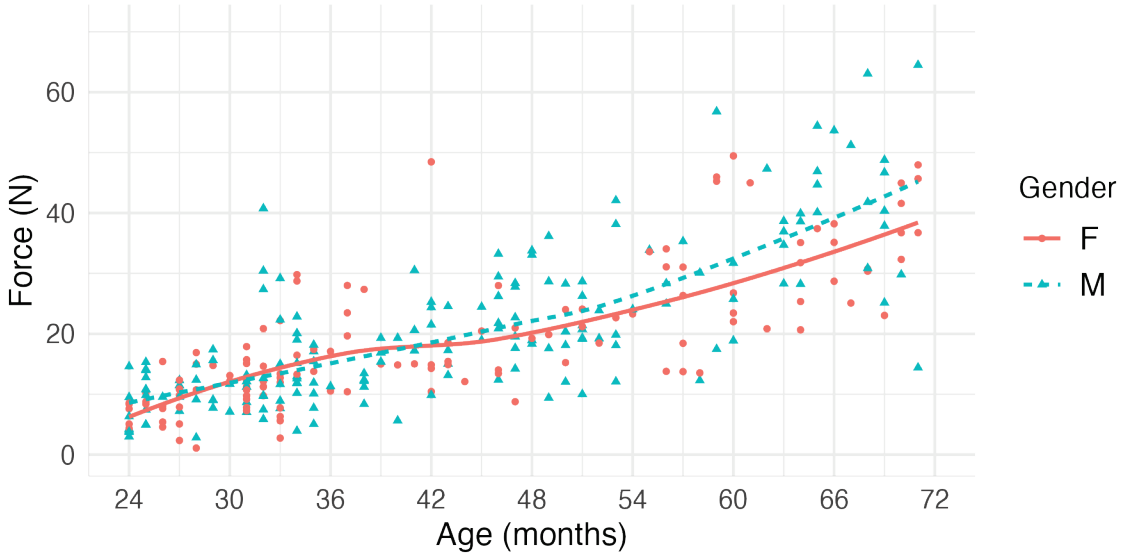
Posture: Standing

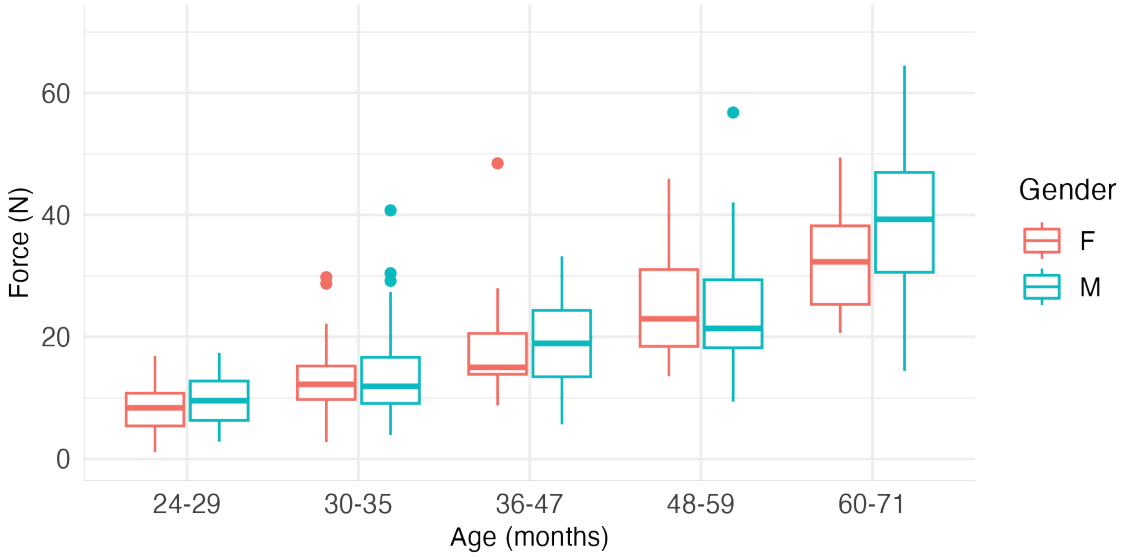
Interface: FingerSurface

Units: Newton



FingerSurface_Thumb_Elbow_Push





FingerSurface_Thumb_Elbow_Push (N)

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	33	9.6	4.1	2.8	3.4	9.6	15.4	17.4
24-29	2.00-2.49	F	25	8.8	4.0	1.1	2.8	8.4	15.3	16.9
24-29	2.00-2.49	Both	58	9.3	4.1	1.1	3.0	9.1	15.4	17.4
30-35	2.50-2.99	M	38	14.1	7.8	3.9	5.7	11.9	29.4	40.8
30-35	2.50-2.99	F	32	13.3	5.9	2.7	6.0	12.2	25.1	29.8
30-35	2.50-2.99	Both	70	13.7	7.0	2.7	5.7	12.1	29.0	40.8
36-47	3.00-3.99	M	37	18.9	6.6	5.6	9.5	19.0	29.7	33.2
36-47	3.00-3.99	F	24	18.2	8.5	8.8	10.4	15.0	28.0	48.5
36-47	3.00-3.99	Both	61	18.6	7.4	5.6	9.8	17.2	29.5	48.5
48-59	4.00-4.99	M	35	24.5	10.0	9.4	11.4	21.4	39.3	56.8
48-59	4.00-4.99	F	20	24.7	9.5	13.5	13.7	23.0	45.3	46.0
48-59	4.00-4.99	Both	55	24.6	9.8	9.4	12.1	22.7	43.0	56.8
60-71	5.00-5.99	M	28	39.4	12.2	14.4	21.1	39.3	60.0	64.5
60-71	5.00-5.99	F	25	33.4	8.9	20.7	21.1	32.3	47.5	49.5
60-71	5.00-5.99	Both	53	36.6	11.1	14.4	20.8	36.7	54.0	64.5

PullApart_HandCouple_Pull

Description: Two-hand opposed maximal pull

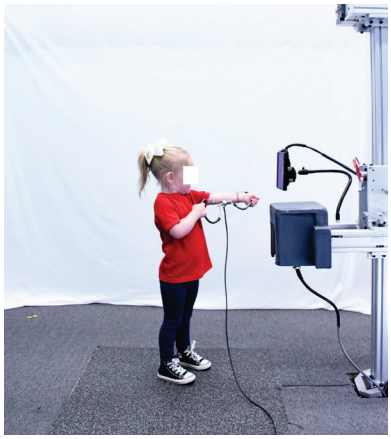
Configuration: Stand

Position: The participant held one handle of the apparatus in each hand and pulled apart while standing.

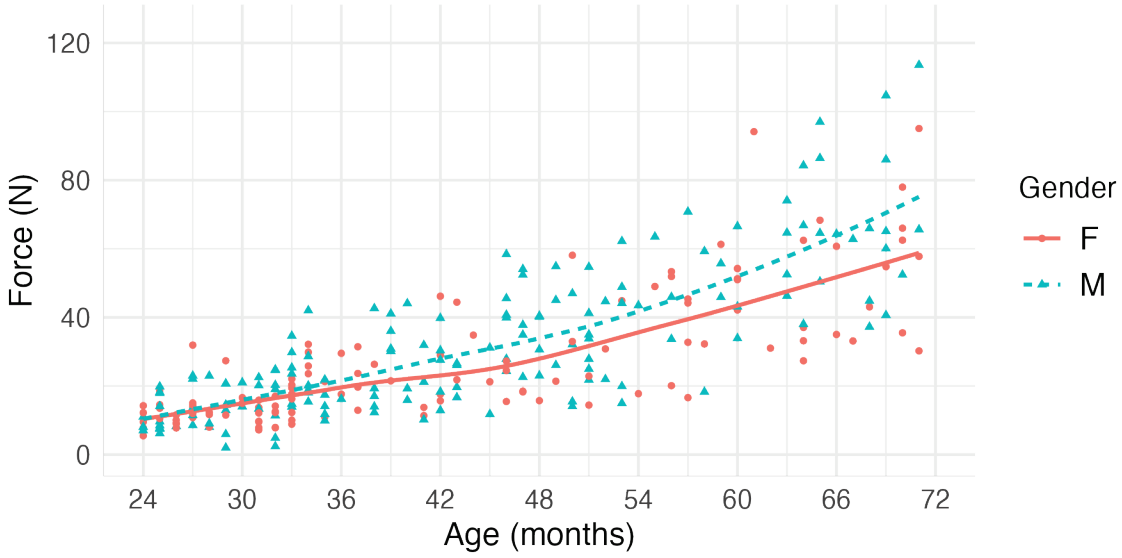
Posture: Standing

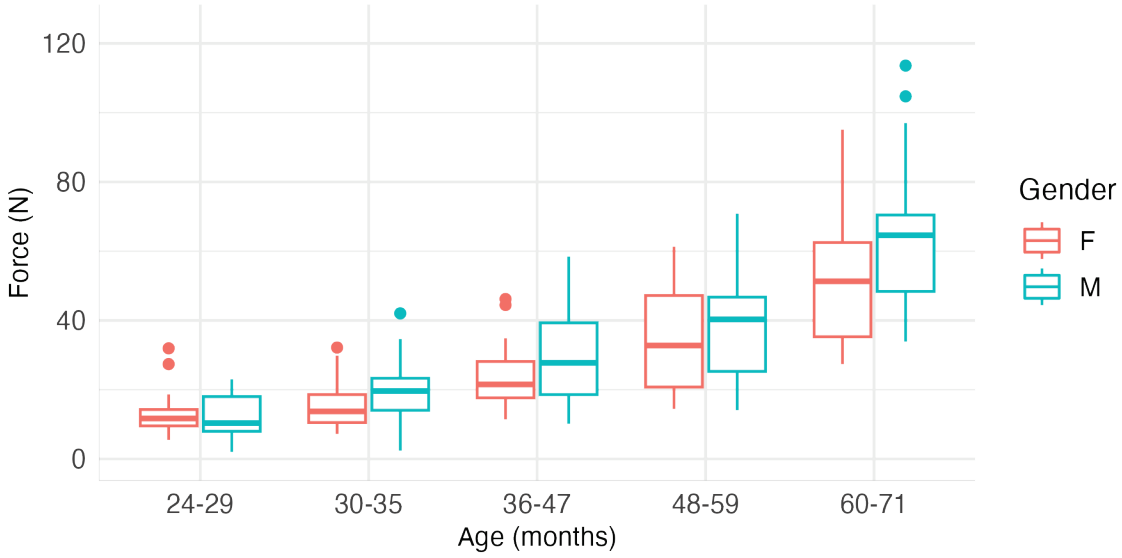
Interface: PullApart_HandCouple

Units: Newton



PullApart_HandCouple_Pull





PullApart_HandCouple_Pull (N)

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	28	12.4	6.0	2.0	6.0	10.4	22.7	23.0
24-29	2.00-2.49	F	25	12.9	5.8	5.5	7.8	11.7	25.6	31.9
24-29	2.00-2.49	Both	53	12.7	5.9	2.0	6.1	11.5	23.0	31.9
30-35	2.50-2.99	M	30	19.4	8.2	2.4	7.2	19.6	32.5	42.0
30-35	2.50-2.99	F	31	15.4	6.4	7.2	7.9	13.7	27.9	32.2
30-35	2.50-2.99	Both	61	17.3	7.6	2.4	7.8	16.3	29.9	42.0
36-47	3.00-3.99	M	38	29.0	12.7	10.2	12.2	27.7	52.7	58.4
36-47	3.00-3.99	F	23	23.6	9.2	11.4	13.0	21.5	43.5	46.2
36-47	3.00-3.99	Both	61	27.0	11.8	10.2	12.3	24.5	46.2	58.4
48-59	4.00-4.99	M	34	38.3	15.3	14.1	15.3	40.3	62.7	70.8
48-59	4.00-4.99	F	19	35.1	15.5	14.4	15.6	32.8	58.4	61.3
48-59	4.00-4.99	Both	53	37.1	15.3	14.1	15.3	35.0	61.7	70.8
60-71	5.00-5.99	M	27	64.2	20.7	33.9	37.5	64.6	102.4	113.6
60-71	5.00-5.99	F	23	52.4	19.4	27.4	30.3	51.3	92.5	95.1
60-71	5.00-5.99	Both	50	58.7	20.8	27.4	32.0	58.9	96.1	113.6

TurnKnob_40mm_Elbow_CW

Description: One-hand clockwise twist exertion

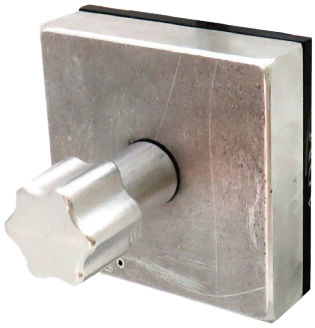
Configuration: Elbow_Stand

Position: The vertical position of the knob was set to 63% of measured stature, approximately elbow height.

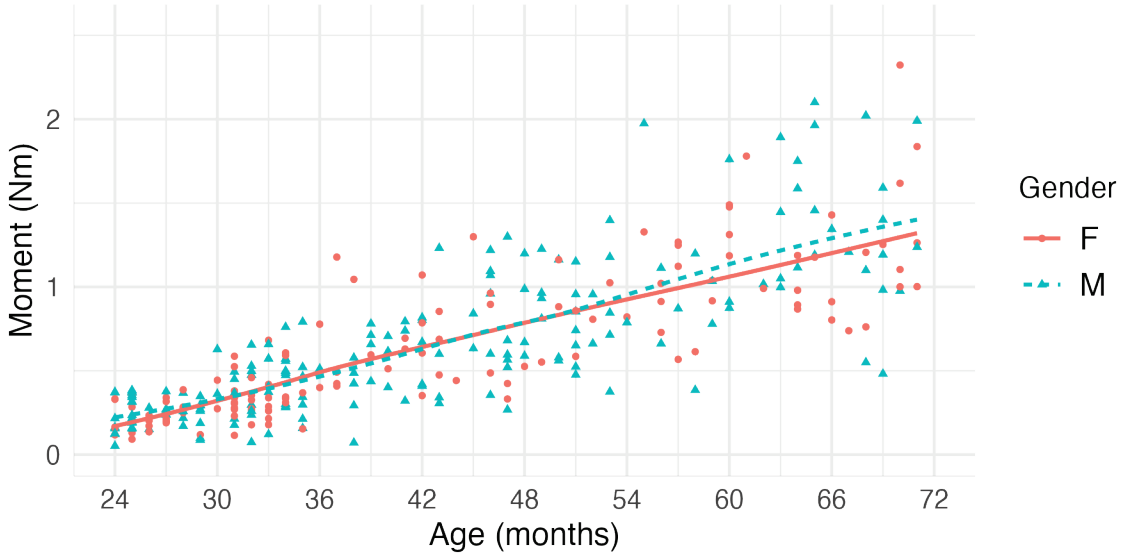
Posture: Standing

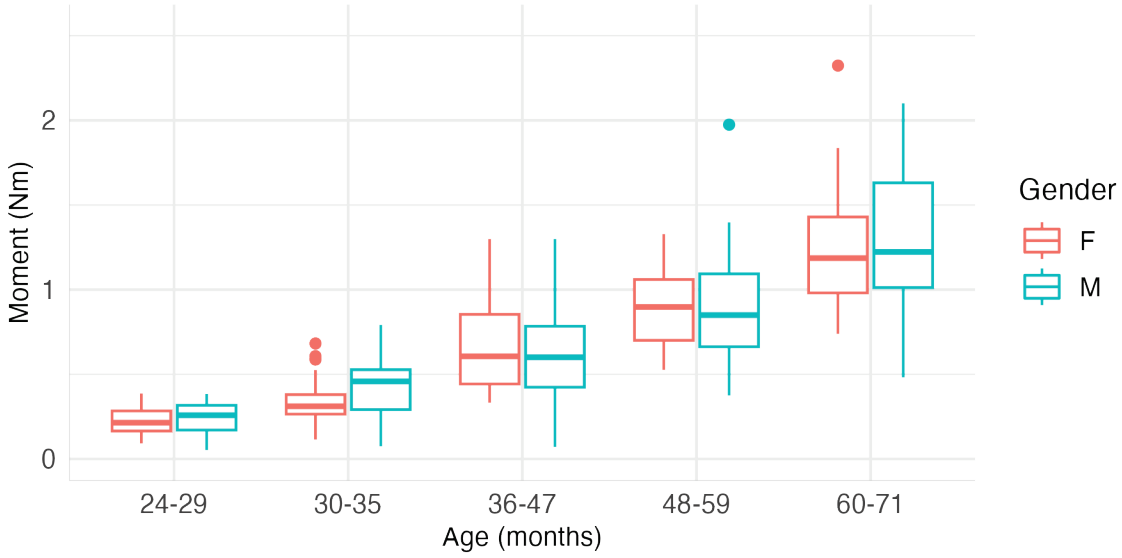
Interface: TurnKnob_40

Units: Newton-meter



TurnKnob_40mm_Elbow_CW





TurnKnob_40mm_Elbow_CW (Nm)

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	41	0.25	0.09	0.05	0.10	0.26	0.38	0.38
24-29	2.00-2.49	F	25	0.23	0.08	0.09	0.12	0.21	0.35	0.39
24-29	2.00-2.49	Both	66	0.24	0.09	0.05	0.10	0.24	0.38	0.39
30-35	2.50-2.99	M	38	0.42	0.18	0.07	0.15	0.46	0.67	0.79
30-35	2.50-2.99	F	33	0.34	0.14	0.12	0.17	0.31	0.60	0.68
30-35	2.50-2.99	Both	71	0.38	0.16	0.07	0.16	0.34	0.66	0.79
36-47	3.00-3.99	M	40	0.63	0.28	0.07	0.29	0.60	1.22	1.30
36-47	3.00-3.99	F	25	0.67	0.28	0.33	0.36	0.61	1.16	1.30
36-47	3.00-3.99	Both	65	0.65	0.28	0.07	0.31	0.60	1.21	1.30
48-59	4.00-4.99	M	34	0.88	0.32	0.38	0.44	0.85	1.29	1.97
48-59	4.00-4.99	F	20	0.90	0.25	0.53	0.55	0.90	1.27	1.33
48-59	4.00-4.99	Both	54	0.89	0.30	0.38	0.51	0.86	1.29	1.97
60-71	5.00-5.99	M	28	1.33	0.44	0.48	0.66	1.22	2.01	2.10
60-71	5.00-5.99	F	25	1.22	0.38	0.74	0.77	1.19	1.83	2.32
60-71	5.00-5.99	Both	53	1.28	0.41	0.48	0.75	1.19	2.00	2.32

PinchPull_19mm_Elbow_Pull

Description: One-hand pinch-pull maximal exertion

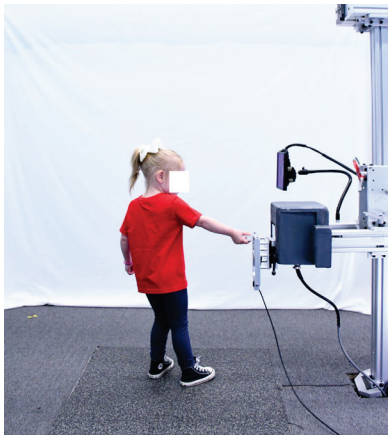
Configuration: Elbow_Stand

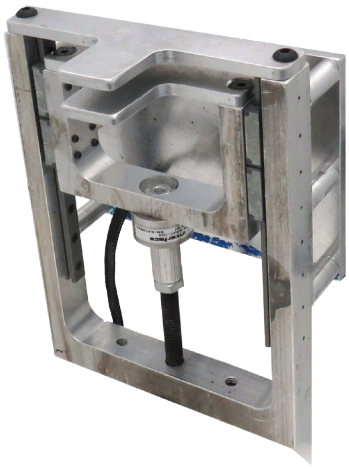
Position: The vertical position of the pinch-pull fixture was set to 63% of measured stature, approximately elbow height.

Posture: Standing

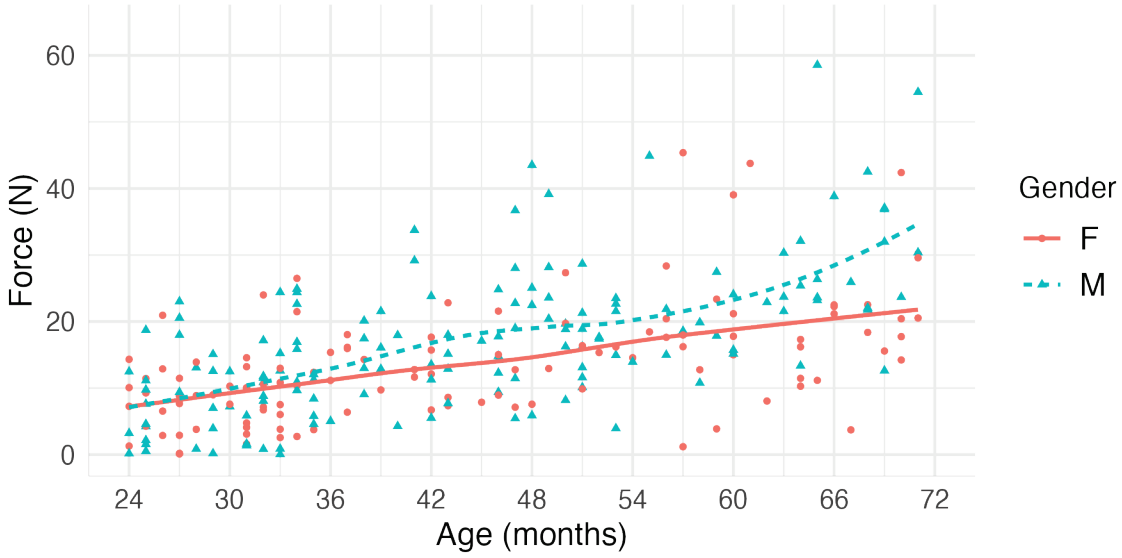
Interface: PinchPull_19

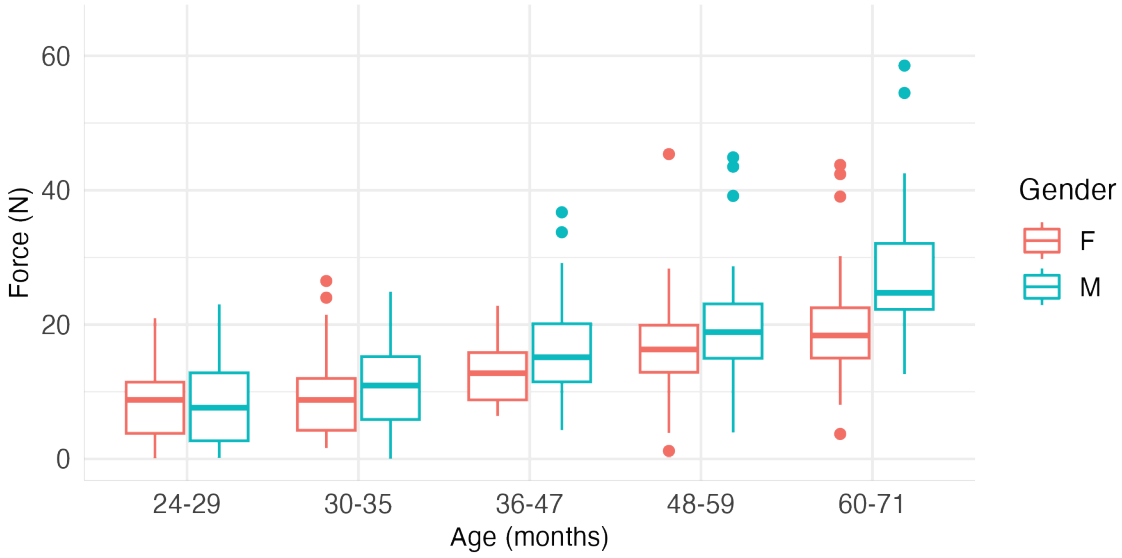
Units: Newton





PinchPull_19mm_Elbow_Pull





PinchPull_19mm_Elbow_Pull (N)

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	23	8.7	7.0	0.2	0.2	7.6	20.4	23.0
24-29	2.00-2.49	F	21	8.0	5.3	0.1	0.2	8.8	14.3	20.9
24-29	2.00-2.49	Both	44	8.4	6.2	0.1	0.2	8.2	20.3	23.0
30-35	2.50-2.99	M	29	11.0	7.2	0.0	0.9	10.9	24.4	24.9
30-35	2.50-2.99	F	26	9.6	6.5	1.6	2.6	8.8	23.4	26.5
30-35	2.50-2.99	Both	55	10.3	6.8	0.0	1.2	10.1	24.4	26.5
36-47	3.00-3.99	M	33	16.4	8.0	4.3	5.3	15.1	31.0	36.7
36-47	3.00-3.99	F	23	12.9	4.7	6.4	6.8	12.8	21.2	22.8
36-47	3.00-3.99	Both	56	15.0	7.0	4.3	5.5	14.3	28.3	36.7
48-59	4.00-4.99	M	35	20.1	9.1	4.0	7.5	18.9	40.5	44.9
48-59	4.00-4.99	F	20	17.3	9.5	1.2	3.7	16.3	29.2	45.4
48-59	4.00-4.99	Both	55	19.1	9.3	1.2	5.3	18.0	40.5	45.4
60-71	5.00-5.99	M	26	28.2	11.3	12.6	13.8	24.7	51.5	58.6
60-71	5.00-5.99	F	25	20.5	10.0	3.7	8.5	18.4	41.7	43.8
60-71	5.00-5.99	Both	51	24.4	11.3	3.7	10.7	22.5	43.1	58.6

ShoulderPush_Elbow_Push

Description: Maximal lateral push with shoulder against a vertical surface

Configuration: Elbow_Stand

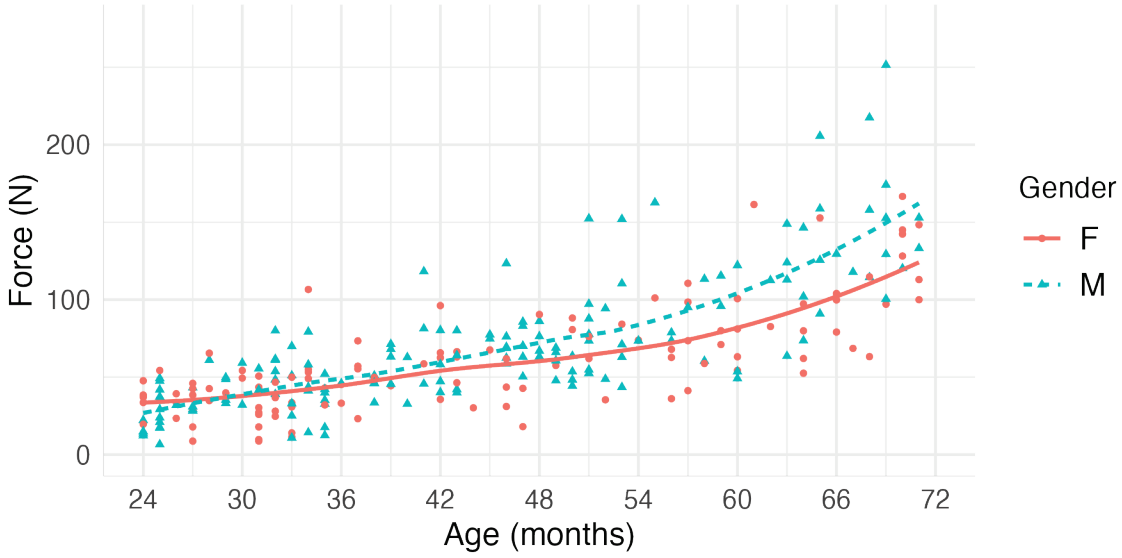
Position: The vertical position of the square pad interface was set to 63% of measured stature, approximately elbow height.

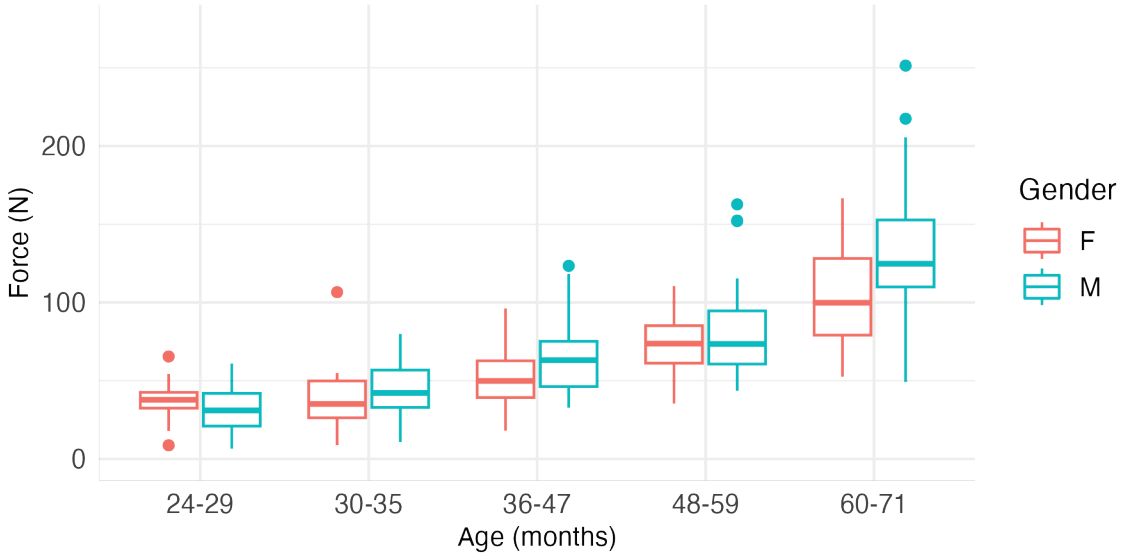
Posture: Standing

Interface: SquarePad

Units: Newton

ShoulderPush_Elbow_Push





ShoulderPush_Elbow_Push (N)

Age Group (months)	Age Group (years)	Gender	N	mean	sd	min	Q.05	Q.50	Q.95	max
24-29	2.00-2.49	M	25	31.2	13.9	6.6	12.6	31.0	49.7	61.0
24-29	2.00-2.49	F	20	36.4	12.8	8.7	17.4	37.8	54.9	65.5
24-29	2.00-2.49	Both	45	33.6	13.5	6.6	12.6	34.8	53.4	65.5
30-35	2.50-2.99	M	27	44.1	18.8	10.8	13.0	42.2	76.5	80.0
30-35	2.50-2.99	F	26	37.8	20.4	8.8	10.1	35.1	54.8	106.6
30-35	2.50-2.99	Both	53	41.0	19.6	8.8	11.1	41.7	73.7	106.6
36-47	3.00-3.99	M	36	63.8	20.4	32.8	38.4	63.1	93.8	123.4
36-47	3.00-3.99	F	23	50.9	18.1	18.1	23.9	49.9	72.8	96.2
36-47	3.00-3.99	Both	59	58.8	20.4	18.1	31.0	58.7	86.8	123.4
48-59	4.00-4.99	M	35	79.8	30.5	43.5	46.8	73.5	152.1	162.7
48-59	4.00-4.99	F	20	72.5	20.6	35.4	36.1	73.7	101.6	110.6
48-59	4.00-4.99	Both	55	77.2	27.4	35.4	42.9	73.5	126.4	162.7
60-71	5.00-5.99	M	28	130.0	46.2	49.2	57.1	124.7	213.3	251.4
60-71	5.00-5.99	F	25	102.3	34.9	52.6	55.9	99.8	159.7	166.6
60-71	5.00-5.99	Both	53	117.0	43.2	49.2	54.0	114.4	186.7	251.4