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YouthShape.US: A New Anthropometric Resource for U.S. Children and Youth

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Abstract

Objective: To characterize the Phase I manual anthropometry component of YouthShape.US, document its 57-measure protocol and quality-control procedures, evaluate selected design-relevant differences from legacy and contemporary national reference data, and introduce the publicly accessible YouthShape.US resource.

Background: Accurate anthropometric data are essential for designing products that safely accommodate children. The most comprehensive U.S. child anthropometry survey was conducted in the 1970s and no longer reflects current populations. Contemporary national sources include few dimensions, while other studies emphasize health outcomes or proprietary sizing systems.

Method: Phase I of YouthShape.US collected laboratory data from 650 children aged 3–17 years. Participants completed a standardized protocol comprising 57 manual anthropometric measurements obtained with calibrated instruments in standing and seated postures, along with body-composition measures.

Results: Comparisons of 90th percentile values across age showed important differences among datasets. Stature and body weight generally tracked contemporary NHANES estimates more closely than the legacy 1970s U.S. child anthropometry values, although some age- and sex-specific deviations were evident. Body weight and waist circumference were substantially larger than values reported in the 1970s, and buttock–knee length was also larger, indicating changes in seated body dimensions relevant to product and environment design.

Conclusion: YouthShape.US establishes the first large-scale, detailed, publicly accessible anthropometric resource for U.S. children and adolescents in more than five decades and demonstrates substantial secular changes, particularly in body-mass-related dimensions.

Application: YouthShape.US provides interactive tools that enable practitioners to explore contemporary body dimensions relevant to product fit, safety, and ergonomic design.

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anthropometry, secular trends, design tools, physical ergonomics, product design

Introduction

Data on the body dimensions of children and youth are critical for designing products and systems that ensure safe, effective, and equitable use. Engineering anthropometry has been used since the mid-20th century to inform the design of nearly every product involving physical human interaction, including clothing, vehicles, medical devices, and protective equipment. Accurate anthropometric data for children and youth are essential for product fit, usability, and safety regulation, including the design of bicycle helmets, child restraints, and pediatric medical devices.

The last large-scale U.S. anthropometric survey focused specifically on children and youth was conducted in the 1970s. Snyder et al. (1977) collected detailed manual anthropometric data from 4,127 children aged 2 weeks to 18 years, creating a foundational dataset for child and youth anthropometry in the United States. The study sampled 16 age groups across this range, with results reported for sexes combined as well as separately for boys and girls. The dataset includes an extensive set of 87 manual body dimensions, encompassing both traditional measures (e.g., stature, sitting height, and limb lengths) and functional measures related to reach, clearance, and posture. These data are publicly available, remain widely cited, and continue to underpin many design standards. However, the population reflects U.S. children from the 1970s and is therefore outdated with respect to secular changes in growth, body composition, and demographic diversity. Subsequent analyses have demonstrated that increases in body mass have altered many key anthropometric dimensions (Pagano et al., 2015), and the current U.S. child population is substantially more diverse than that represented in the Snyder dataset.

The largest contemporary U.S. child anthropometry dataset is available through the National Health and Nutrition Examination Survey (NHANES). This ongoing, nationally representative study includes children and adolescents from birth through 19 years of age. NHANES anthropometric measures include stature, body weight, waist circumference, and selected limb lengths (e.g., upper arm and upper leg length in participants aged 8–19 years) (Fryar et al., 2021). NHANES also includes body composition measures such as skinfold thickness in selected cycles. While NHANES provides unparalleled sample size and population representativeness through sampling weights, it includes limited dimensional detail, inconsistent anthropometric measures across survey cycles, and lacks posture-specific or functional dimensions relevant to ergonomic analysis and product design.

The NHANES National Youth Fitness Survey (NNYFS) was a one-time, nationally representative survey conducted in 2012 to assess physical fitness, physical activity, and related health behaviors among U.S. children aged 3–15 years (CDC, 2012). Implemented as a supplement to NHANES, NNYFS included basic anthropometric measures (stature, body mass, and waist circumference), standardized fitness testing, and objective physical activity monitoring. Compared with NHANES and the Snyder et al. (1977) survey, NNYFS provides stronger linkage between growth and physical fitness but includes far fewer anthropometric dimensions and was not designed as a comprehensive anthropometric reference dataset.

The Shape Up!/Shape Up! Kids study developed and validated methods for estimating health and body composition from two-dimensional (2D) optical images and three-dimensional (3D) whole-body surface scans (Tian et al., 2020, 2023). The central objective was to use external body shape to predict internal health characteristics, such as body fat percentage and lean mass, enabling scalable assessment of health risk. The study measured approximately 720 children and adolescents aged 5–17 years and collected a set of manual anthropometric measures (e.g., stature, body mass, waist circumference, waist-to-hip ratio, and selected girths), along with optical 2D/3D body imaging and extensive health assessments, including DXA-derived body composition, MRI-based measures, strength testing, biochemical markers, and questionnaire-based behavioral data. Although Shape Up! gathered rich data linking body shape to health and function, it was not designed as a comprehensive anthropometric reference dataset; it includes only a small number of manual dimensions and lacks posture-specific whole-body anthropometry required for ergonomic design and product fit. Moreover, the data are not publicly accessible.

Size North America, a large-scale sizing effort led by Human Solutions (now Humanetics Digital) and designed primarily for apparel applications, measured approximately 2,200 children in the United States aged 6–17 years (Kuebler et al., 2019; Seidl et al., 2016). The survey emphasizes laser-based three-dimensional body scanning acquired in three standing postures and one seated posture, with minimal collection of manual anthropometric measurements. A predefined set of scan-derived lengths, breadths, and circumferences (extracted in accordance with ISO 7250, 1996 and ISO 8559, 1989) can be accessed through commercial software; no public access is available.

The Kidsize study, conducted by the Instituto de Biomecánica de Valencia (IBV), collected 3D body shape data from approximately 1,000 Spanish children aged 3–12 years using a mobile app–based scanning approach to support the development of children's apparel and consumer products (Ballester et al., 2015, 2016). The study emphasized scan-derived size assignment, fit prediction, and the generation of virtual mannequins representing European children by age group. These outputs are primarily disseminated through proprietary online tools. IBV subsequently conducted the Euro-Hand-Feet study, which collected detailed 3D shape data of the hands and feet of Spanish children aged 4–14 using scan-based methods. Similar to Kidsize, these data were developed to support apparel, footwear, and equipment design applications and are made available mainly through derived models and commercial tools.

More recently, TU Delft, in collaboration with IBV, and other partners, completed data collection for the KidsCAN study, which includes children from birth through 16 years of age (https://kidscantudelft.webflow.io/). Preschool-aged children (0–3 years) were primarily assessed using manual anthropometric measures with supplemental hand and foot scans, whereas primary- (4–10 years) and secondary-school–aged children (12–15 years) were measured using both manual anthropometry and 3D scanning of the body, hands, and feet. Outputs from KidsCAN are intended to support the development of sizing standards and design tools used by designers and engineers, including resources disseminated through European standards organizations such as the European Committee for Standardization (CEN) and digital databases such as DINED. As with earlier IBV-led efforts, publicly accessible resources consist of aggregated measurement ranges, proportions, and representative 3D models.

In the United States, child and youth ergonomics and apparel-oriented studies have often relied on convenience samples to collect a limited set of anthropometric dimensions for specific applications (e.g., classroom furniture design), resulting in datasets that are typically small and narrow in scope (Oyewole et al., 2010). With the exception of commercially distributed sizing surveys, there remains a lack of current, publicly accessible U.S. anthropometric reference datasets spanning childhood and adolescence (Dianat et al., 2018).

The University of Michigan Transportation Research Institute (UMTRI) has conducted a series of automotive-focused studies that collected detailed anthropometric and postural data from children approximately 6 months to

12 years of age to support the development of child human surrogates for crash safety evaluation (e.g., Jones et al., 2018; Park et al., 2015, 2017; Park & Reed, 2015; Reed et al., 2005; Weber et al., 1985). Although these studies provide high-quality, task-specific data relevant to vehicle design and occupant protection, they do not include adolescents and were based on relatively small samples with limited diversity.

Taken together, existing U.S. datasets are limited in one or more critical respects: they provide only a restricted set of anthropometric dimensions, lack posture-specific or functional measures, are based on outdated populations, focus on narrow application domains, or are not publicly accessible. No contemporary, publicly available U.S. resource integrates detailed manual anthropometry with 3D body shape, body composition, and physical capability measures across childhood and adolescence. More broadly, child and youth anthropometric datasets remain scarce, and public access to such data is uncommon.

YouthShape.US was developed to address this gap by applying modern data collection methods and a carefully designed sampling strategy, with an emphasis on accessibility, usability, and translation to practice. The overall objective of the YouthShape.US study is to establish an anthropometric resource for U.S. children and adolescents that links body size and shape with physical capability. Pairing detailed anthropometry with measures of activity and function is critical for applications in product fit and sizing, protective equipment design, health and exposure modeling, and safety evaluation, where body dimensions alone are insufficient to characterize how children interact with products and environments during real-world use.

Going beyond data, YouthShape.US aims to provide open, practitioner-facing resources to support translation of anthropometric research into design and safety practice. A publicly accessible web platform (YouthShape.US) is now available that goes beyond the typical univariate summaries provided in printed anthropometric resources. By emphasizing design tools as well as data, YouthShape.US aims to lower barriers to evidence-based design for children and adolescents.

In the first phase of YouthShape.US, detailed data were gathered from 650 children and youth ages 3 through 17 years in a laboratory setting. In addition to extensive 3D surface scans, more than 50 manual anthropometric measurements were obtained using standardized methods. These measurements capture dimensions that cannot be obtained reliably from surface scans, provide reference data for comparison and linkage with other datasets, and support analyses relating anthropometry, body shape, and functional measures. Subsequent phases use targeted or streamlined subsets of the scalar measures to support broader demographic and geographic expansion. The objective of this paper is to document the methods and quality-control procedures used for the complete Phase 1 manual anthropometry protocol, characterize the study sample, and evaluate selected design-relevant differences relative to legacy and contemporary national reference data. The manuscript therefore highlights the scientific and design value of the uniquely detailed Phase 1 manual dataset. Complete summary statistics for all 57 Phase 1 manual anthropometric measures are documented in a companion UMTRI technical report (Jones et al., 2026), while comprehensive, interactive, and continually updated summaries of scalar anthropometric data from all phases are provided through the YouthShape.US online data browser.

Methods

Participants

Boys and girls aged 3 through 17 years were eligible to participate. Both child participants and their caregivers were required to speak and understand English to provide informed consent and to follow study instructions. Participants were recruited through the University of Michigan's public-facing research volunteer portal (https://UMHealthResearch.org), as well as through social media posts and flyers distributed at local schools, recreation centers, and day-care facilities. Caregivers received a cash stipend for a laboratory data collection visit lasting up to 2.5 hours.

All study recruitment materials and procedures were reviewed and approved by a University of Michigan Institutional Review Board (IRB ID: HUM00231054). All procedures were noninvasive and posed no greater than minimal risk to participants. Written informed consent was obtained from caregivers prior to participation. Written assent was obtained from children aged 10–17 years, and oral assent was obtained from children aged 3–9 years using an age-appropriate scripted procedure. Participation was voluntary, and caregivers and children could withdraw at any time without penalty or loss of compensation.

All study personnel interacting with child participants completed human-subjects training and background verification procedures. In accordance with best practices for research involving children, a caregiver accompanied the child throughout testing, and at least two research investigators were present during all data collection activities.

Laboratory Setting and Participation Preparation

Data collection took place in laboratories at the University of Michigan Transportation Research Institute (UMTRI). The body measurement laboratory used included a private changing area, and access during data collection sessions was restricted to authorized study personnel, participants, and caregivers.

Prior to measurement, participants changed into close-fitting exercise apparel provided by the study. All participants wore elastic shorts extending to approximately mid-thigh; female participants additionally wore a sports bra over their own bra, if applicable. Privacy was maintained through restricted laboratory access and dedicated changing areas.

Demographic information (e.g., age, sex, and race/ethnicity) was collected for each child participant using a structured questionnaire. The questionnaire was completed by the caregiver and participant together, by the participant with caregiver guidance, or by the caregiver on behalf of the participant, depending on the child's age and preference. Questionnaires were administered using paper forms, an online platform (Qualtrics), or verbally, based on participant or caregiver preference and logistical considerations.

Manual Anthropometric Measurement

For manual anthropometric measurements, participants were positioned in standardized standing or seated postures and instructed to remain still for brief periods to ensure measurement accuracy. Figure 1 shows images demonstrating some of the data collection methods. Investigators provided clear instructions and actively monitored posture and alignment during measurement. When needed, particularly for younger children, a second investigator assisted to help maintain proper positioning and minimize extraneous movement.

Across all measurement tasks, pacing was adjusted to the child's age, attention, and tolerance while maintaining standardized protocols. Brief movement breaks were incorporated between static measurement tasks as needed to reduce restlessness and support sustained cooperation. These procedures balanced the need for high-quality, repeatable measurements with the developmental needs and comfort of child participants.

The 57 manual anthropometric dimensions listed in Table 1 were collected using standardized protocols aligned, where possible, with prior large-scale anthropometric surveys and established anthropometric measurement references. Primary measurement-definition sources included Snyder et al. (1977), Gordon (1989), and the U.S. Army and Marine Corps Anthropometric Surveys measurer handbook (Hotzman et al., 2011). Definitions from Gordon et al. and Hotzman et al. are referred to as "ANSUR" definitions. These sources provided landmark definitions, participant postures, and

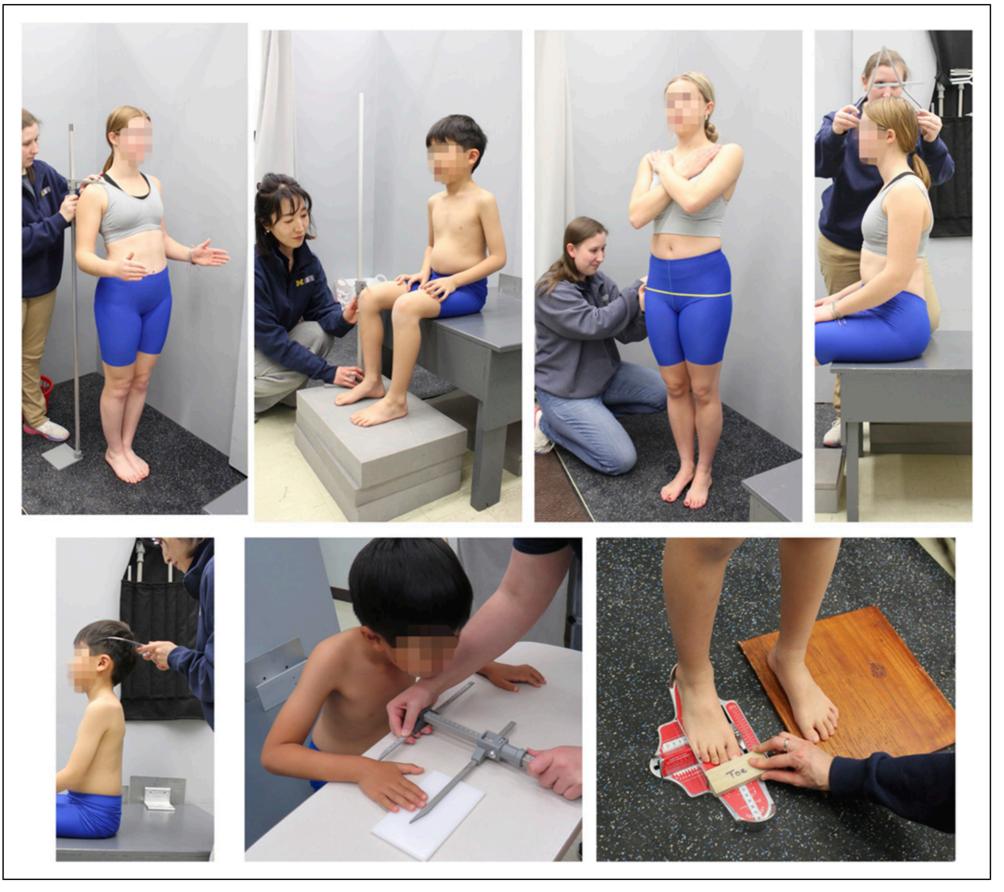

Figure 1. Representative images demonstrating manual anthropometric measurement procedures used in YouthShape.US. Images are staged demonstrations. The children shown are not study participants

instrument-placement guidance for comparable dimensions. Measures were selected to support harmonization with existing datasets, enable linkage with 3D body shape data, and capture dimensions not reliably derived from 3D scans alone. Full measurement definitions and landmark descriptions are maintained in the YouthShape.US online resource and supporting technical documentation.

Measurements were obtained using calibrated anthropometers, sliding and spreading calipers, flexible steel measuring tapes, and a Brannock device, as appropriate. Measures were selected to (1) support harmonization with existing datasets (e.g., NHANES), (2) enable linkage with 3D body shape data, and (3) capture dimensions not reliably derived from 3D scans alone. Anatomical landmarks were identified using standardized definitions consistent with established anthropometric reference protocols. Foot length and breadth were measured using a Brannock device. Interpupillary distance was measured using a handheld digital pupillometer (Veatch HX-400; Veatch Ophthalmic Instruments, Temecula, CA, USA).

Body mass and body composition (percent fat and lean mass) were measured using a Tanita SC-331S bioelectrical impedance analysis scale (Tanita Corporation, Tokyo, Japan). Body mass and percent body fat were recorded as the average of two consecutive measurements, to the nearest 0.1 kg and 0.1%, respectively. Participants stood barefoot in a

Table 1. Covariates and anthropometric variables included in the Phase 1 YouthShape.US manual anthropometry dataset

A. Participant covariates

Variable
Sex
Age, months
Age, years
Hispanic ethnicity
Race, U.S. Census categories
Handedness
User language

B. Anthropometric, body composition, and derived variables

Category	Variable
Body size and composition	Body weight
	BMI
	Percent body fat
	Fat mass
	Fat-free mass
Standing dimensions	Stature
	Stature with shoes
	Acromion height
	Anterior-superior iliac spine height
	Cervicale height
	Iliac crest height
	Posterior-superior iliac spine height
Sitting dimensions	Erect sitting height
	Acromion height, sitting
	Eye height, sitting
	Knee height, sitting
	Popliteal height, sitting
	Thigh clearance height
	Elbow rest height
	Buttock–knee length
Breadths and depths	Bideltoid breadth
	Bispinous breadth, pelvis
	Chest breadth
	Chest depth, scapula
	Chest depth, spine
	Hip breadth
	Hip breadth, sitting
	Pelvis depth

(continued)

Table 1. (continued)

B. Anthropometric, body composition, and derived variables	
Category	Variable
Circumferences	Chest circumference
	Chest circumference, underbust
	Waist circumference, natural indentation
	Waist circumference, omphalion
	Buttock circumference
	Neck circumference
	Wrist circumference, proximal
	Wrist circumference, stylion
Upper-extremity dimensions	Acromion–elbow length
	Elbow–fingertip length
Hand and finger dimensions	Hand breadth
	Finger length, middle
	Finger diameter, index, right 1
	Finger diameter, index, right 2
	Finger diameter, middle, right 1
	Finger diameter, middle, right 2
	Finger diameter, ring, right 1
	Finger diameter, ring, right 2
	Finger diameter, pinkie, right 1
	Finger diameter, pinkie, right 2
	Finger diameter, thumb, right 1
Head dimensions	Head breadth
	Head circumference
	Head length
	Interpupillary distance
	Tragion to top of head
Foot dimensions	Foot breadth, Brannock
	Foot length, Brannock
Lower-extremity dimensions	Lateral malleolus height

Note. Measurement definitions were aligned, where possible, with Snyder et al. (1977), Gordon (1989), and the U.S. Army and Marine Corps Anthropometric Surveys measurer handbook (Hotzman et al., 2011, referred to as ANSUR). BMI was derived from stature and body weight. Percent body fat, fat mass, and fat-free mass were obtained from body composition measurements. Detailed landmark definitions and measurement procedures are maintained in the YouthShape.US online resource.

standardized posture, with a foam spacer placed between their legs to ensure consistent limb separation and electrode contact.

Training, Quality Control, and Repeatability and Reproducibility

All study personnel completed structured training prior to data collection, followed by formal repeatability and reproducibility (R&R) assessments conducted during training and periodically throughout the study to monitor measurement drift. Training began with review of written protocols, including landmark definitions and measurement procedures. Team members practiced as a group to align landmark interpretation and instrument placement, followed by individual practice. Training was organized by anatomical region (head, hand, foot, seated, standing). One measurer then completed the full protocol under observation by an experienced anthropometrist, who confirmed procedural consistency.

Inter-rater reliability was initially assessed by having all measurers independently measure the

Table 2. Representative R&R results compared with ANSUR benchmark values

Dimension	Measurement type	Study MAD (mm)	ANSUR allowable error (mm)	Study CV (%)	ANSUR CV (%)	Interpretation
Stature without shoes	Standing height	1.4–8.2	6	0.1–0.6	3.9	Generally comparable; upper range exceeded ANSUR benchmark
Erect sitting height	Seated height	1.8–4.6	6	0.3–0.7	3.9	Comparable
Buttock–knee length	Seated length	0.9–6.6	6	0.7–2.7	4.9	Comparable/slight upper-range exceedance
Bideltoid breadth	Breadth	4.2–9.6	8	1.4–2.4	6.4	Generally comparable; upper range exceeded ANSUR benchmark
Hip breadth	Breadth	2.4–8.2	6	1.3–8	7.0	Variable; upper range exceeded ANSUR benchmark
Waist circumference, omphalion	Circumference	2.6–21.0	12	0.5–1.4	11.6	Variable; upper range exceeded benchmark; soft-tissue measure
Chest circumference	Circumference	7.3–18.8	14	1.0–2.8	8.3	Generally comparable; upper range exceeded benchmark; soft-tissue measure
Head breadth	Head dimension	0.9–1.6	2	0.5–1.4	3.5	Comparable
Foot length, Brannock	Foot dimension	0.6–1.3	3	0.3–0.7	4.8	Comparable
Cervicale height	Landmark height	2.6–7.4	4	0.3–0.6	4.2	Variable; upper range exceeded benchmark; landmark-sensitive

Note. MAD = mean absolute difference; CV = coefficient of variation. Study = YouthShape Phase 1. YouthShape values are shown as the range across R&R training Rounds 4 and 5. ANSUR benchmark values are from the U.S. Army and Marine Corps Anthropometric Surveys measurer handbook. R&R sessions were conducted on student and adult volunteers and should be interpreted as procedural quality checks rather than direct estimates of measurement error in child participants.

same three adult volunteers (study team members). Results were reviewed collectively and discrepancies were discussed. A second inter-rater round was conducted on three additional volunteers, with mean, range, standard deviation, and coefficient of variation (CV), computed for each dimension.

Subsequent R&R rounds incorporated both inter- and intra-rater assessment. All measurers independently assessed two volunteers, with at least one repeated measurement to assess intra-rater consistency. Mean absolute differences (MAD), CVs, and standard errors were computed and compared with published benchmarks from the U.S. Army and Marine Corps Anthropometric Surveys measurer handbook (ANSUR; Hotzman et al., 2011). ANSUR benchmarks were used as external reference values for evaluating whether measurement variability was within ranges expected for trained anthropometric data collection. Because the R&R assessments were conducted primarily on student and adult volunteers rather than child participants, and because adults generally have greater body size and soft-tissue variability, these comparisons were interpreted as procedural quality checks rather than direct estimates of measurement error in the study population. Representative comparisons are shown in Table 2.

Periodic spot-check R&R sessions were conducted throughout data collection to identify potential drift. R&R procedures covered most anthropometric dimensions, including heights, segment lengths, breadths, depths, circumferences, hand and finger measures, foot dimensions, and seated measures. Emphasis was placed on maintaining measurement accuracy, recognizing that precision may vary across dimensions.

Data Quality Assessment and Outlier Detection

Quality control procedures were applied to all scalar anthropometric and body composition variables using bivariate visualization and tolerance-based outlier detection. Each measure was plotted against anatomically or physiologically relevant reference variables (e.g., stature, age, and BMI), with linear fits used to assess expected proportional relationships.

Dimension-specific tolerances were defined based on instrument precision, developmental variability, and prior laboratory experience with child and youth anthropometry. Standing heights were evaluated relative to stature (20–60 mm tolerances), sitting heights relative to each other and stature (40–60 mm), segment lengths relative to stature and adjacent segments (25–60 mm), breadths relative to stature, BMI, and related transverse measures (50–100 mm), depths relative to stature, age, and associated breadths (20–40 mm), and circumferences relative to stature, BMI, and anatomically related dimensions (30–200 mm and 30–80 mm, respectively).

Hand, wrist, head, and foot dimensions were evaluated using tighter internal proportional tolerances (2–70 mm) with foot measures additionally checked against stature and paired landmarks (10–20 mm). Body composition outputs were evaluated for internal physiological consistency (e.g., BMI vs. percent fat; fat mass vs. impedance), with ±2 unit tolerances applied.

Flagged values were individually reviewed to distinguish anthropometric variability from data entry errors, unit inconsistencies, device artifacts, or posture-related deviations. Values attributable to recording error were corrected when documentation permitted; otherwise, implausible values were excluded. Selected measures were cross-checked against corresponding 3D scan–derived dimensions to verify anatomical consistency.

Results

Participants

A total of 650 children aged 3–17 years participated in the study. Table 3 summarizes the number of male and female participants. Table 4 presents the distribution of race and ethnicity based on caregiver responses to the demographic questionnaire. Hispanic ethnicity and race were collected as separate items using question formats aligned with U.S. federal reporting standards and consistent with approaches used in NHANES and the U.S. Census and American Community Survey. Specifically, ethnicity was categorized as Hispanic or Latina/o, not Hispanic or Latina/o, or prefer not to answer, and race allowed selection of one or more categories (American Indian or Alaska Native, Asian, Black or

Table 3. Age Distribution by Sex

Age (yr)	F	M	Both	%
3	17	15	32	4.9
4	21	19	40	6.2
5	17	18	35	5.4
6	16	18	34	5.2
7	22	24	46	7.1
8	23	19	42	6.5
9	21	24	45	6.9
10	20	20	40	6.2
11	18	24	42	6.5
12	26	26	52	8.0
13	22	30	52	8.0
14	28	28	56	8.6
15	23	28	51	7.8
16	22	25	47	7.2
17	22	14	36	5.5
	318	332	650	100

Table 4. Distribution of Race and Hispanic Ethnicity

Category	N	% of participants	U.S. Population[a]
Asian/Pacific Islander	67	10.3	6%
Black	83	12.8	14%
Hispanic	56	8.6	27%
White	438	67.4	48%
Other categories including 2 or more races or NA	6	0.9	5%
Total	650	100.0	100%

[a]For age <18 years from American Community Survey data summarized at https://datacenter.aecf.org/data/tables/103-child-population-by-race-and-ethnicity

African American, Native Hawaiian or other Pacific Islander, White, or prefer not to answer). For reporting purposes, race and ethnicity responses were combined into mutually exclusive categories (Asian/Pacific Islander, Black, Hispanic, White, and Other). Although these social categories are specific to the U.S. context, self-reported race and ethnicity are known to be associated with systematic differences in anthropometric variables. Failure to consider these categories can contribute to disproportionate disaccommodation of certain subpopulations; therefore, these distributions are reported. Relative to the U.S. child and youth population (<18 years old), the sample shows reasonable representation of Asian, Black, and White children, with Hispanic children underrepresented.

Summary Statistics

Complete age- and sex-specific summary statistics for all 57 Phase 1 manual anthropometric measures are documented in the companion UMTRI technical report (Jones et al., 2026). Interactive summaries are also available through the YouthShape.US online data browser, which allows users to compute age- and sex-specific statistics, examine distributions, and generate cross-plots for selected anthropometric variables. Users should interpret high and low percentile estimates in relation to the selected age range and sample size, particularly for narrowly defined age-sex groups. Figure 2 illustrates two complementary types of summaries supported by the browser, using acromion height as an example: continuous age-related trends and grouped age- and sex-stratified distribution summaries.

Comparison With Other Studies

YouthShape.US was motivated in part by evidence that the Snyder et al. (1977) dataset no longer provides accurate design guidance for contemporary populations (Pagano et al., 2015). Accordingly, we examined differences between the current sample and Snyder, as well as the extent to which the current sample reflects the U.S. population as reported by Fryar et al. (2021) using data from 2015–2018 NHANES. Although a newer NHANES anthropometric reference has been published (Fryar et al., 2025), we retained the 2015–2018 reference as the primary national comparator because it is the most recent pre-pandemic NHANES reference and is more directly comparable with prior NHANES reports used to evaluate secular trends. The more recent data have fewer children and youth and consequently the published statistics are not aggregated in 1-year bins. Because NHANES includes a limited set of anthropometric dimensions, comparisons with NHANES were restricted to stature and body weight, stratified by sex. For Snyder, additional comparisons were conducted for waist circumference and buttock knee length, two dimensions of particular relevance for design and seating applications that show clear contrasts between

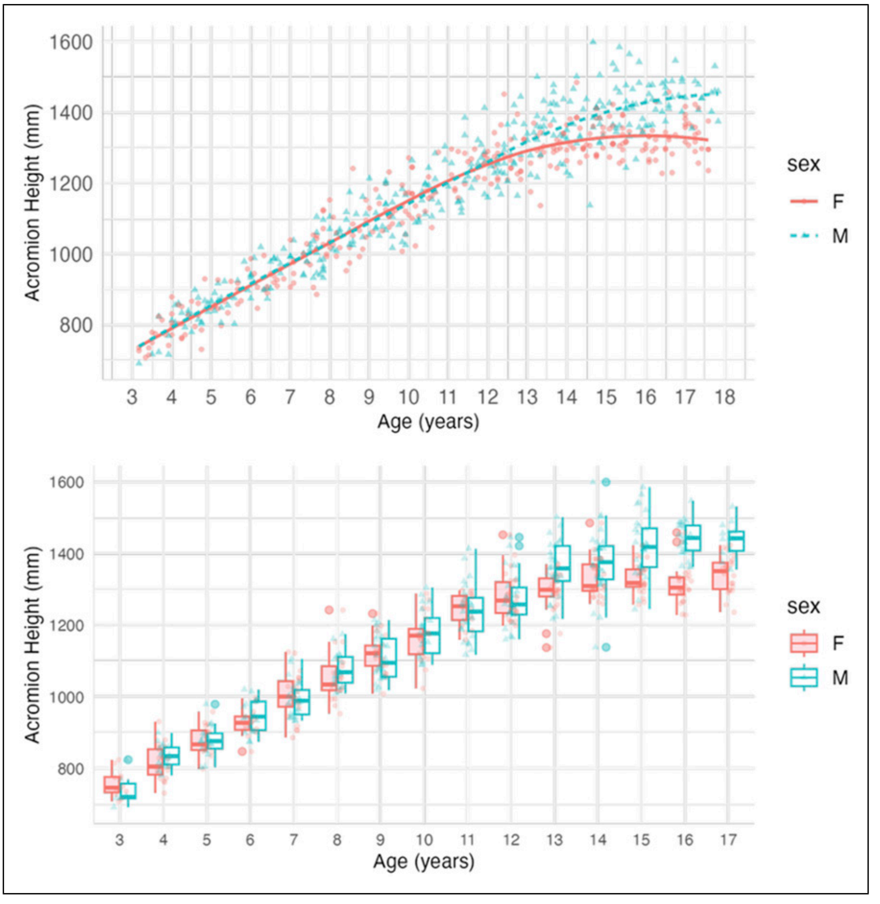

Figure 2. Example summary plots illustrating types of analyses supported by the YouthShape.US data browser, using acromion height as an illustrative variable. The upper panel shows individual participant values and fitted age trends by sex; the lower panel shows age- and sex-stratified distribution summaries

studies. These dimensions were selected to contrast measures expected to be strongly influenced by secular changes in body mass, such as body weight and waist circumference, with measures more closely related to skeletal growth or seated accommodation, such as stature and buttock–knee length.

Figures 3 and 4 show comparisons to summary statistics from Snyder and Fryar. Because the upper tails of most dimensions are where the secular population trends are expected to be most consequential for design, the plots show 90th percentile values. We chose the 90th percentile because NHANES does not consistently report 95th percentile values for all age-sex groups and because some age-sex strata in the current sample include as few as 14 participants. Accordingly, the percentile estimates presented here should be interpreted as descriptive indicators of broad age- and sex-related patterns rather than precise design limits for individual age-sex strata, particularly where sample sizes are small. To improve stability of the percentile estimates from the current sample, age bins were defined using a ±1-year window around the target age. For example, the mean age for 10 year olds is 10.5 years; the quantiles for 10 year olds were computed using data from children who were 9.5 to 11.5 years old. For Snyder, we analyzed the original data, re-binning using integer age bins (e.g., children

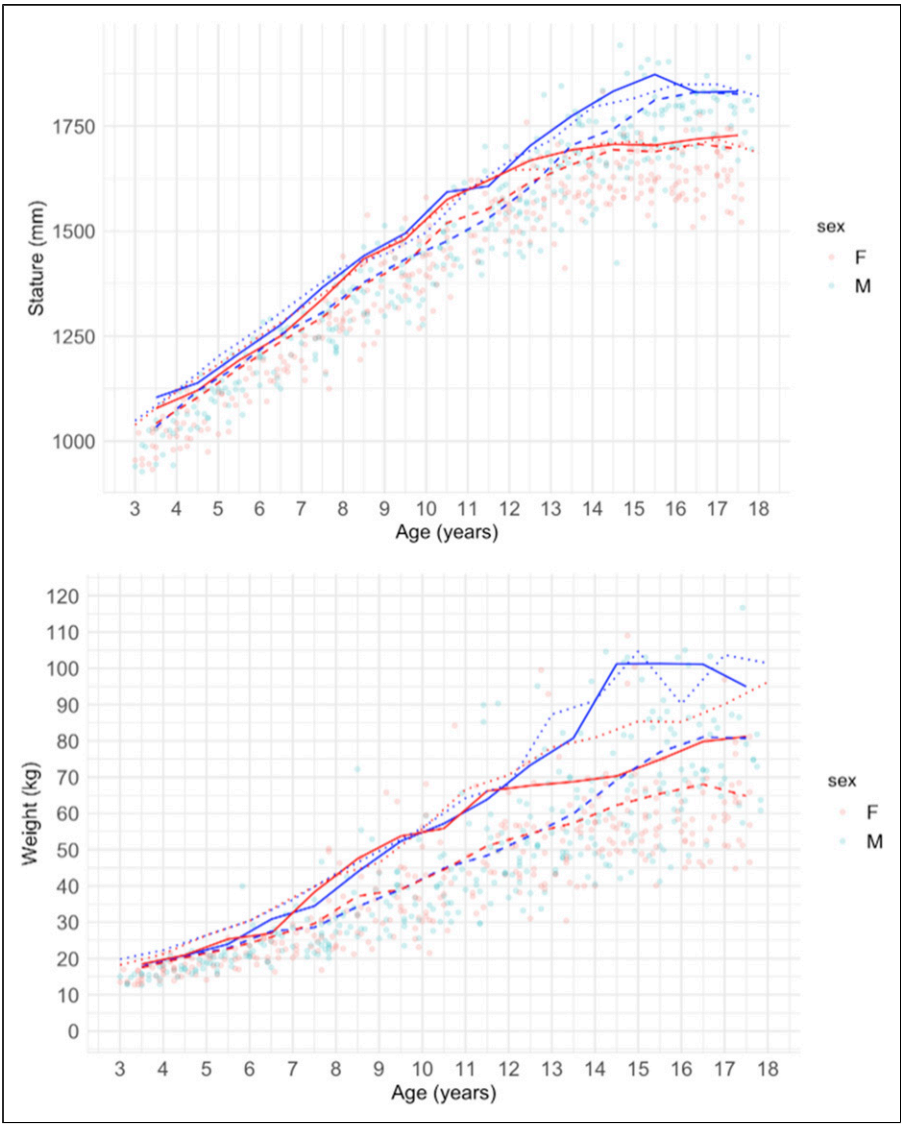

Figure 3. Comparison of 90th percentile stature and body weight by age and sex across YouthShape.US, Snyder et al. (1977), and NHANES/Fryar et al. Points represent individual anthropometric measurements collected during Phase 1 of YouthShape.US. Solid lines represent YouthShape.US 90th percentile values, dashed lines represent Snyder et al. (1977), and dotted lines represent NHANES/Fryar et al. Color distinguishes females and males

at least 48 months old but less than 60 months old are categorized as 4 years old), rather than the half-year bins used in the published report.

Figure 3 shows that the stature values in the current sample generally track the NHANES 90th percentiles for both male and female participants across most ages, although some deviations are evident during adolescence. In contrast, the Snyder stature values are markedly lower during mid-childhood, particularly from approximately ages 8 to 12 for girls and 8 to 16 for boys.

For body weight, the current sample tracks the NHANES 90th percentile reasonably well

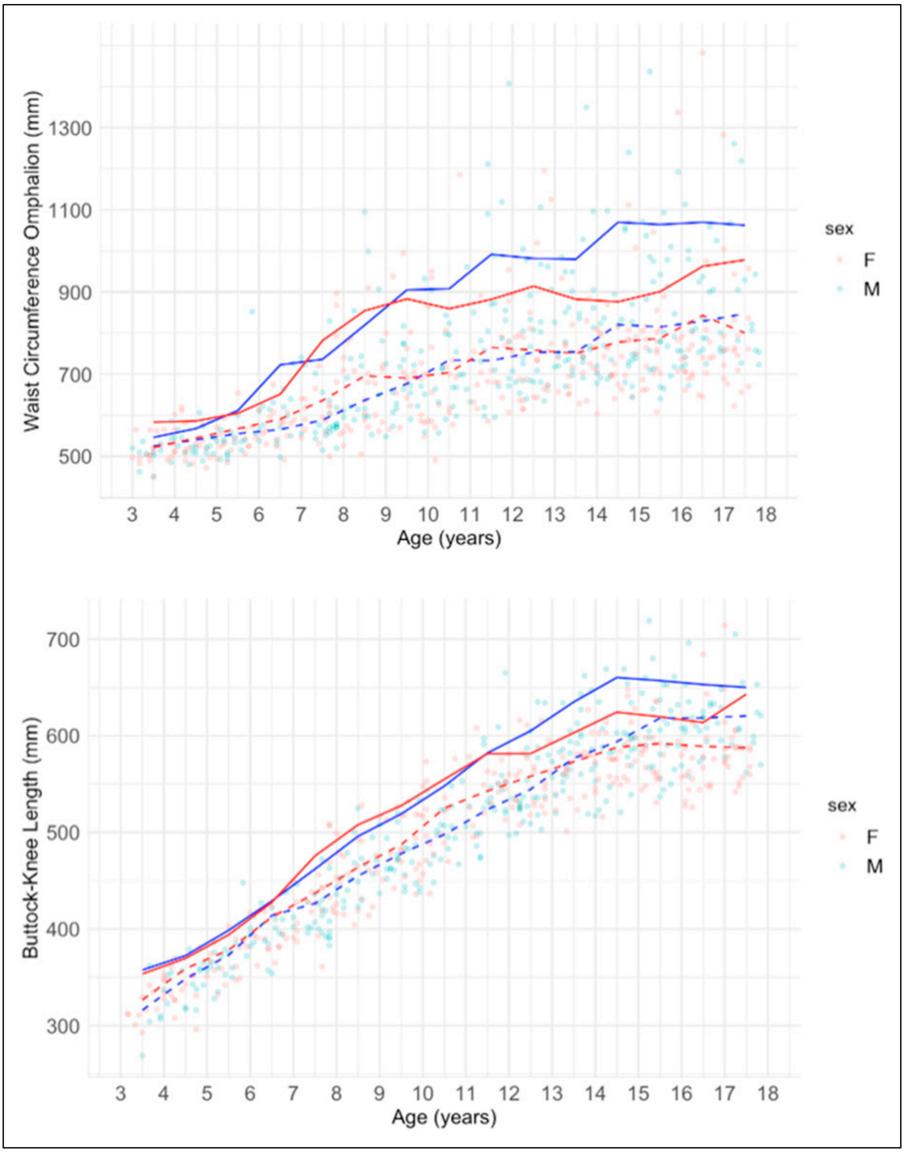

Figure 4. Comparison of 90th percentile waist circumference at the omphalion and buttock–knee length by age and sex between YouthShape.US and Snyder et al. (1977). Points represent individual anthropometric measurements collected during Phase 1 of YouthShape.US. Solid lines represent YouthShape.US 90th percentile values, and dashed lines represent Snyder et al. (1977) values. Color distinguishes females and males

through approximately age 12 for both sexes, although some deviations are evident. At the youngest ages, the current sample falls below the NHANES 90th percentile, consistent with underrepresentation of children at the upper end of the body weight distribution. However, because the sample begins at age 3, the ±1-year windowing approach systematically biases the estimates for 3-year-olds upward. Among adolescent girls, the current-sample 90th percentile values are substantially lower than corresponding NHANES values, indicating under-sampling at the upper tail of the body weight distribution.

Differences in upper-quantile body weight between the current sample and Snyder are substantial. By approximately ages 10 to 12, 90th percentile body weight values in both NHANES and the current sample are approximately 15–20 kg greater than the corresponding Snyder values. These differences indicate substantial secular change in body weight and in body dimensions strongly associated with body mass.

Figure 4 compares the 90th percentiles of waist circumference and buttock-knee length between the current sample and Snyder (comparable NHANES data are not available for these dimensions). Waist circumference values are consistently larger in the current sample than in Snyder, with differences emerging by approximately age six and increasing to more than 100 mm at older ages. Given the undersampling of higher body weight adolescent girls in the current sample, these discrepancies likely underestimate true differences between contemporary populations and Snyder. Buttock-knee length, influenced by both overall body size (stature) and body weight, is also systematically larger in the current sample. Differences of approximately 50 to 70 mm were observed at the 90th percentile across ages 9 to 12 years, indicating meaningful changes in seated body dimensions relevant to product and environment design.

Discussion

YouthShape.US is the first large-scale study in more than 50 years to provide publicly accessible anthropometric data for U.S. children and adolescents. This paper reports manual anthropometry results from Phase 1, focusing on dimensions that illustrate two contrasting patterns: substantial secular change in body-mass-related dimensions and greater stability in dimensions more closely associated with skeletal growth. Body weight and waist circumference showed the clearest divergence from Snyder et al. (1977), whereas stature and body weight generally tracked contemporary NHANES estimates more closely than the legacy Snyder values, although some deviations were evident across age and sex groups. This focused comparison provides a direct interpretation of the Phase 1 data while directing readers to the companion UMTRI technical report for complete summary statistics for the 57-measure protocol and to the YouthShape.US data browser for interactive and continually updated analyses.

These findings are directly relevant to designers and engineers working on products and environments that must safely and effectively accommodate children, including clothing, protective equipment, furniture, and other consumer products. The substantial increases in upper quantiles of body weight-related dimensions have direct implications for product design, sizing systems, and safety standards, and underscore the importance of distinguishing dimensions affected by changes in body composition from those influenced primarily by skeletal growth.

The representativeness of the current sample was evaluated with respect to race/ethnicity and to the upper quantiles of stature and body weight, for which national representative estimates are available from NHANES. Overall, the sample tracked NHANES closely for stature and body weight across much of the age range. However, children with higher body weight were undersampled, notably for boys and girls aged 3–6 years and for adolescent girls. This pattern reflects a well-documented challenge in anthropometric surveys, as individuals with higher body weight may be reluctant to participate due to weight-related stigma. In addition, some of the undersampling relative to NHANES is likely attributed to the underrepresentation of Hispanic participants in the current sample, a group that has higher upper body weight quantiles in national data.

The results reported here represent Phase 1 of YouthShape.US, which emphasized comprehensive data collection during a single, extended laboratory session. In addition to more than 50 manual anthropometric measures, the study collected whole-body laser scans in approximately 25 postures and high-resolution

3D scans of the head, hands, and feet, and recorded measures of strength, body composition, and physical fitness (Jones et al., 2024). Phase 2 of the study will focus on improving the distribution of race and ethnicity representation, adding data from more than 800 Black and Hispanic children. Phase 3 will expand the dataset through the collection of a smaller set of measures from more than 3,000 children across multiple sites.

YouthShape.US was developed not only as a data collection effort but also as a practitioner-facing resource. The YouthShape.US web portal (https://YouthShape.US) hosts an interactive data browser that provides access to the scalar anthropometric data, allowing users to compute quantiles for selected age range, examine relationships among variables through cross-plots, and conduct exploratory analyses relevant to design and safety applications. The data browser will be updated as results from Phases 2 and 3 become available. Because later phases collect targeted subsets of the Phase 1 scalar measures, the Phase 1 dataset remains the primary source for the full 57-measure manual protocol, whereas the online browser provides the appropriate mechanism for integrating the more scalable data collected across subsequent phases. Once sufficient data are available from Hispanic participants, we plan to generate weighted datasets that provide population-representative estimates for the U.S. children and adolescents, using NHANES as the reference. A recent publication demonstrated the methodology for converting the weighted, stratified NHANES sample into an unweighted, synthesized distribution using continuous, parametric methods (Parkinson & Reed, 2026).

This study highlights the need to revisit many existing design standards and practices that rely on outdated child and youth anthropometric data. Although YouthShape.US data are not currently incorporated into standards, anthropometric data have historically informed both U.S. and international standards through test devices, clearance requirements, fit envelopes, and product sizing guidance. YouthShape.US provides contemporary evidence that can support future evaluation and revision of such standards, particularly where current guidance relies on outdated child body-dimension data. While some dimensions have remained relatively stable over time, the substantial increases observed in dimensions related to increases in body weight underscore the risk of disaccommodation when older data are used. For example, clothing patterns and size charts based on the older data should be updated to reflect the current distribution of body dimensions. The discrepancy in the upper quantiles of buttock-knee length suggests that school furniture developed using the 1970s data may be inadequate for current students. The design of many other products for children, such as car safety seats and belt positioning boosters, should be reviewed in light of these findings. YouthShape.US provides a foundation for addressing these challenges by offering an up-to-date, expandable, and accessible anthropometric resource to support evidence-based design for children and youth.

Key Points

- YouthShape.US establishes a contemporary anthropometric resource for U.S. children and adolescents aged 3–17 years.
- Manual anthropometry from 650 participants provides updated reference values for body dimensions relevant to product and environment design.
- Comparisons with historical datasets show substantial increases in dimensions associated with body mass.
- Changes in seated dimensions, including buttock–knee length, have implications for seating and product design.
- Results are translated into publicly accessible interactive tools to support evidence-based design and safety evaluation.

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References

Ballester, A., Piérola, A., Parrilla, E., Uriel, J., Piqueras, P., Nácher, B., Vivas, J., Pérez, C., Jerónimo, S. S., & Alemany, S. (2016). Kidsize: Always get the right size. In *Proceedings of the 7th international conference on 3D body scanning technologies*. Lugano, Switzerland, November.

Ballester, A., Valero, M., Nácher, B., Piérola, A., Piqueras, P., Sancho, M., Gargallo, G., González, J. C., & Alemany, S. (2015). 3D body databases of the Spanish population and its application to the apparel industry. In *Proc. of 6th int. Conf. on 3D body scanning technologies*. Lugano.

Centers for Disease Control and Prevention (CDC). (2012). *National Youth Fitness Survey (NNYFS): Plan and operations, 2012*. National Center for Health Statistics.

Dianat, I., Molenbroek, J., & Castellucci, H. I. (2018). A review of the methodology and applications of anthropometry in ergonomics and product design. *Ergonomics*, *61*(12), 1696–1720. https://doi.org/10.1080/00140139.2018.1502817

Fryar, C. D., Gu, Q., Afful, J., Carroll, M. D., & Ogden, C. L. (2025). *Anthropometric reference data for children and adults*. United States, August 2021–August 2023.

Fryar, C. D., Gu, Q., Ogden, C. L., & Flegal, K. M. (2021). Anthropometric reference data for children and adults: United States, 2015–2018. *Vital and health statistics, series 3, no. 46*. National Center for Health Statistics.

Gordon, C. C. (1989). *1988 anthropometric survey of US army personnel: Methods and summary statistics*. Technical Report Natick/TR-89/044.

Hotzman, J., Gordon, C. C., Bradtmiller, B., Corner, B. D., Mucher, M., Kristensen, S., Paquette, S., & Blackwell, C. (2011). *Measurer's handbook: US army and marine corps anthropometric surveys, 2010-2011*. U.S. Army Natick Soldier Research, Development, and Engineering Center. Technical Report TR-11-017.

ISO 7250. (1996). *Basic human body measurements for technological design*.

ISO 8559. (1989). *Garment construction and anthropometric surveys– body dimensions*.

Jones, M. H., Park, B. K., Ebert, S. M., Miller, C. S., Robinson, L. E., & Reed, M. P. (2026). *YouthShape.US: Summary statistics for manual anthropometric measures from the laboratory pilot study*. UMTRI Technical Report 2026-4.

Jones, M. H. L., Ebert, S. M., Reed, M. P., & Klinich, K. D. K. (2018). Development of a three-dimensional body shape model of young children for child restraint design. *Computer Methods in Biomechanics and Biomedical Engineering*, *21*(15), 784–794. https://doi.org/10.1080/10255842.2018.1521960

Jones, M. L., Ebert, S. M., Miller, C. S., Park, B. K. D., Jung, H., Wood, A., Robinson, L. E., & Reed, M. P. (2024). Laboratory methods for a pilot study of the US YouthShape survey of child and youth anthropometry and physical capability. In *Proceedings of the Human Factors and Ergonomics Society*

Annual Meeting (*68*, No. 1, pp. 193–198). Sage Publications. https://doi.org/10.1177/10711813241278285

Kuebler, T., Luebke, A., Campbell, J., & Guenzel, T. (2019). Size north America–The New North American Anthropometric Survey. In *International conference on human-computer interaction* (pp. 88–98)Springer International Publishing.

Oyewole, S. A., Haight, J. M., & Freivalds, A. (2010). The ergonomic design of classroom furniture/computer workstation for first graders in the elementary school. *International Journal of Industrial Ergonomics*, *40*(4), 437–447. https://doi.org/10.1016/j.ergon.2010.02.002

Pagano, B., Parkinson, M. B., & Reed, M. P. (2015). An updated estimate of the body dimensions of U.S. children. *Ergonomics*, *58*(6), 1045–1057. https://doi.org/10.1080/00140139.2014.1000392

Park, B.-K., Lumeng, J. C., Lumeng, C. N., Ebert, S. M., & Reed, M. P. (2015). Child body shape measurement using depth cameras and a statistical body shape model. *Ergonomics*, *58*(2), 301–309. https://doi.org/10.1080/00140139.2014.965754

Park, B.-K., & Reed, M. P. (2015). Parametric body shape model of standing children ages 3 to 11 years. *Ergonomics*, *58*(10), 1714–1725. https://doi.org/10.1080/00140139.2015.1033480

Park, B.-K. D., Ebert, S., & Reed, M. P. (2017). A parametric model of child body shape in seated postures. *Traffic Injury Prevention*, *18*(5), 533–536. https://doi.org/10.1080/15389588.2016.1269173

Parkinson, M. B., & Reed, M. P. (2026). Generating a representative anthropometric dataset for U.S. children and youth. *Applied Ergonomics*, *135*, 104764. https://doi.org/10.1016/j.apergo.2026.104764

Reed, M. P., Ebert-Hamilton, S. M., Manary, M. A., Klinich, K. D., & Schneider, L. W. (2005). A new database of child anthropometry and seated posture for automotive safety applications. *SAE Transactions: Journal of Passenger Cars - Mechanical Systems*, *114*(6), 2222–2235. https://doi.org/10.4271/2005-01-1837

Seidl, A., Trieb, R., Wirsching, H. J., Smythe, A., & Guenzel, T. (2016). SizeNorthAmerica - The New North American anthropometric survey: Conceptual design, implementation and results. In *Advances in physical ergonomics and human factors: Proceedings of the AHFE 2016 international conference on physical ergonomics and human factors, July 27-31, 2016, Walt Disney world®, Florida, USA* (pp. 457–468). Springer International Publishing.

Snyder, R. G., Spencer, M. L., Owings, C. L., Schneider, L. W., & Howells, G. A. (1977). *Anthropometry of infants, children, and youths. University of Michigan Transportation Research Institute*. University of Michigan Transportation Research Institute. Final report UM-HSRI-77-17.

Tian, I. Y., Ng, B. K., Wong, M. C., Kennedy, S., Hwaung, P., Kelly, N., Liu, E., Garber, A. K., Curless, B., Heymsfield, S. B., & Shepherd, J. A. (2020). Predicting 3D body shape and body composition from conventional 2D photography. *Medical Physics*, *47*(12), 6232–6245. https://doi.org/10.1002/mp.14492

Tian, I. Y., Wong, M. C., Nguyen, W. M., Kennedy, S., McCarthy, C., Kelly, N. N., Yong, Y. E., Garber, A. K., Heymsfield, S. B., Curless, B., & Shepherd, J. A. (2023). Automated body composition estimation from device-agnostic 3D optical scans in pediatric populations. *Clinical Nutrition*, *42*(9), 1619–1630. https://doi.org/10.1016/j.clnu.2023.07.012

Weber, K. W., Lehman, R. J., & Schneider, L. W. (1985). *Child anthropometry for restraint system design*. University of Michigan Transportation Research Institute. UMTRI technical report 85-23.

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