Size, strength and physical exposure differences between adult and child computer users

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Abstract

The goal of this study was to determine whether there were differences in musculoskeletal exposures between children and adults when they use standard and child proportional computer input devices. The first part of this study consisted of a systematic review of child and adult anthropometry. The results indicated that when five-year-old children start to use computers in school, they are one-half to two-thirds the size and about one-fourth as strong as their adult counterparts. The second part of this study had 14 children between 5 to 8 years of age and their same-gender biological parent (28 subjects total) perform a standardized mousing task using both a standard and child-proportional sized mouse. The results from the laboratory study corroborated the anthropometric findings. When using the standard mouse, children worked with 18.4º ± 11.3º ($p < 0.0001$) greater ulnar deviation and 9.4º ± 12.9º ($p < 0.0001$) less extension than their adult counterparts. When children used the child-proportional devices, ulnar deviation was reduced by 4.0º ± 6.4º ($p = 0.04$) with very little change in extension. Children applied twice the relative force to the mouse button compared to their adult counterparts. The findings of the study may have applications in the design of computer input devices for children.

Keywords: children, computers, input devices, anthropometry, posture

1. Introduction

Computer use in school-age children has been increasing rapidly in the last two decades due to the lower age at first use and the rising number of usage hours per day. There is a large body of research on computer use and musculoskeletal disorders in adults; however, paediatric data are sparse. It was recently reported that among adults who were newly hired into jobs requiring 15 or more hours of computer work per week, more than 50% developed some form of musculoskeletal symptoms in the first year [1]. Similarly, in a recent cross-sectional study that surveyed 152 sixth grade children, more than 50% reported musculoskeletal discomfort in the prior year that they thought was exacerbated by computer use [2].

Given that children's physical structure is not fully formed, and the presence of computer-related injuries in adults, it is possible that the musculoskeletal health of child computer users may be at risk. The physical well-being of a generation of workers may be affected even before they enter the workforce.

Studies that have investigated gender differences in computer work have shown that women apply higher relative forces, have higher muscular activity, and work with greater range of motion in the wrist [3] while operating the computer and have significantly higher prevalence for many types of musculoskeletal disorders [4]. If these risk factors are due in part to size differences, then children may be at an even greater disadvantage since size and strength differences are even more pronounced between children and adults than between adult males and females.

2. Methods

2.1. Anthropometry survey

A systematic assessment of child and adult anthropometry was carried out utilizing data from United States and United Kingdom populations, using data published in CHILDATA [5] and ADULTDATA [6]. Of primary interest were the anthropometric measurements of 5, 10, and 14-year-olds, because of the distinct school populations these ages represent. Designing the survey of available anthropometry data in this manner enabled the comparison of children entering elementary, middle, and high school in the context of computer input device design. Specific measures considered were shoulder breadth, hand width and length, finger length, wrist depth, and pinch force as a surrogate measure for hand strength. These anthropometric measures were studied since it was thought they may have an influence in the upper extremity postures and forces used to operate computer input devices.

2.2. Subjects

14 healthy schoolchildren (7 female, 7 male) between the ages of 5 and 8, along with their same-gender biological parent (total of 28 participants), were recruited from a usability evaluation subject database maintained by Microsoft Corporation. Sample size was chosen to be similar to other studies where differences in physical exposures were demonstrated between males and females [3]. Exclusionary criteria were assessed by telephone screening and included the following: the parent not being the same-sex biological parent of the child participant; any history of injury that would affect normal range of motion in the upper extremities; left-hand mouse use; and inability to manipulate simple objects with a computer mouse.

2.3. Experimental setup

In order to measure physical exposures during computer work, subjects sat in adult-sized adjustable height chairs at an adjustable height work surface. To accommodate the seating of the smaller-sized children, platforms were placed on the floor to support the feet properly and additional back support was provided so the children could sit comfortably. The experiment was a repeated measures design and consisted of subjects performing a series of standardized mousing tasks with both a standard and a smaller sized mouse (see Fig. 1). Device size and task order were randomized.

The standard mouse was a 12.6 cm long, 6.8 cm wide by 4.0 cm high Microsoft IntelliMouse weighing approximately 86 grams (Model #92654; Microsoft Corp.; Redmond, WA). The smaller mouse was 8.8 cm long, 5.1 cm wide by 3.4 cm high weighing approximately 47 grams (Model #K72114G; Kensington Corp.; San Mateo, CA) and was roughly 3/4 the size of a standard mouse. The smaller mouse was chosen because it was proportionally smaller in size, based on anthropometric calculations, reflecting the anticipated size differences between our adult and child computer users.

Figure 1: Standard and small mice used in the exposure assessment

To promote an array of static and dynamic activities in the right arm, subjects performed a series of standardized pointing and clicking tasks using both the standard-sized and smaller-sized mouse. The omni-directional pointing task consisted of alternately clicking on 18 evenly spaced targets arranged in a large circle.

2.4. Data collection

An electrogoniometer (Model #SG-65; Biometrics; Gwent, UK) and was used to measure wrist angle. The goniometer signals were collected at 1000 Hz on a portable data logger system (Muscle Tester ME6000; Mega Electronics; Kuopio, Finland).

2.5. Data analysis

For the selected anthropometric measures from the CHILDATA [5] and ADULTDATA [6] anthropometric databases, data were entered into Microsoft Excel and normal distribution graphs were generated based on the mean and standard deviation of the anthropometric data for children of ages 5, 10, 14, and adults. The maximum static force that can be exerted between the thumb and index finger was used and a measure for strength capacity. From this data, three types of comparisons were made: 1) the proportional differences in child and adult anthropometric measurements based on age, 2) gender differences in anthropometry based on age, and 3) the proportional differences in child and adult strength capacities.

From the laboratory study, the goniometry data was analyzed and mean postural values were calculated for each subject. In addition maximal index finger forces were calculated by having subject press as hard as they could on a Jamar pinch meter. Three trials were performed and the highest trial was used as a measure of the subject's Maximum Voluntary Contraction (MVC). The computer mouse button forces were measured by placing weights directly on top and normal to the surface of the mouse button at the location where the mouse button made contact with the electromechanical switch underneath. Relative finger forces, expressed as a %MVC, were calculated by dividing the mouse button activation force by the subject's index finger MVC.

Between child and adult subject groups, statistical comparisons were made using repeated-measures analysis of variance (RANOVA) methods with electrogoniometer/postural and finger force data.

3. Results

3.1 Anthropometry survey

A summary of some of the anthropometry data is shown in Figure 2. Shoulder breadth, hand breadth, hand length, and finger width dimension differences in centimetres for 5-year-old, 10-year-old, and adult males are reported. The differences between the smallest (5th percentile 5-year-old female) and largest (95th percentile adult male) categories are expressed as percentages. The difference column illustrates that 5-year-old children are 1/2 to 2/3 the size of grown-ups when they start to use computers. Largest differences in parentheses are those between 5th percentile 5-year-old females and 95th percentile adult males [5, 6].

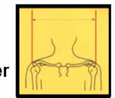
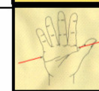
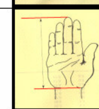
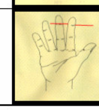
		5-year-old 50%tile Male (cm)	Adult 50%tile Male (cm)	Difference average difference (largest difference)
Shoulder Breadth		25.0	41.3	65% (99%)
Hand Breadth		6.0	8.7	45% (91%)
Hand Length		12.5	19.0	52% (97%)
Finger Width		1.2	1.8	53% (83%)

Figure 2: Summary of four anthropometric measurements. Average differences are the differences between mean 5-year-old values and mean adult values.

Adult males are 4.5 times stronger than their five-year-old male counterparts (see Fig. 3). Adjusted values were charted in which values were normalized to the strength of a five-year-old male. For females this difference follows a similar pattern but is not as pronounced (data not shown).

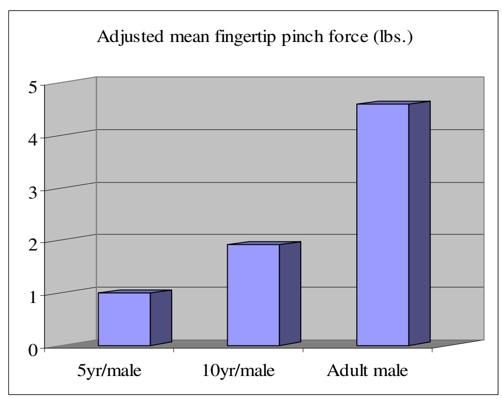


Figure 3: Adjusted mean pinch force between index finger and thumb, normalized to a 5-year-old male [5, 6].

3.2 Subject characteristics

Table 1 shows the demographic data of the study population. There was an equal number of male and female children (and same gender parents). The mean age was 6.6 for the children and 41.8 for the adults. All subjects used their right hand to operate the computer mouse.

Table 1: Study population demographics (n=28)

Child subjects (n=14)		**Adult** subjects (n=14)	
Gender			
Male	7 (50%)	Male	7 (50%)
Female	7 (50%)	Female	7 (50%)
Age			
5	3 (21%)	30-39	5 (36%)
6	4 (29%)	40-49	8 (57%)
7	3 (21%)	50-59	1 (7%)
8	4 (29%)		
Mean	6.6 ± 1.2	Mean	41.8 ± 5.6

3.3. Differences between adults and children on standard mice

When operating the standard mouse, the children worked with 9.4° less wrist extension (20.1° vs. 29.4°, $p < 0.0001$) and 18.4° greater ulnar deviation (16.8° vs. -1.6°, $p < 0.0001$) compared to their parents (see Fig. 4). Children had almost twice the range of motion in both flexion/extension (F/E) (16.5° versus 8.9°) and radial/ulnar (R/U) deviation (15.6° verses 8.2°) compared to adults.

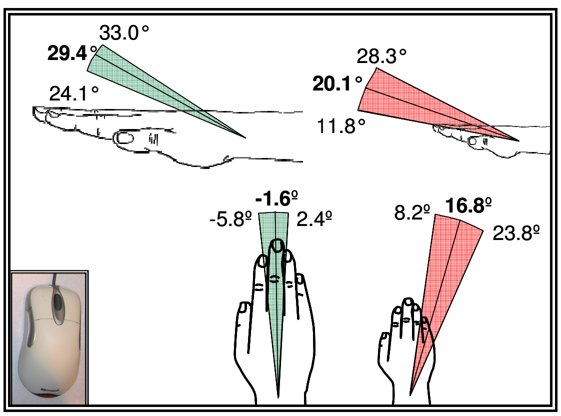


Figure 4: Illustration of wrist posture differences between children and adults on standard mouse (n=28)

3.3. Differences between standard and small mice in children

Children's wrist posture while using standard and small mice were averaged across all mousing tasks. Differences in wrist extension between the two mice were not significant. Children worked with significantly greater ulnar deviation ($p < 0.0001$) on the standard mouse than on the smaller mouse (16.8° versus 12.8°) (see Fig. 5).

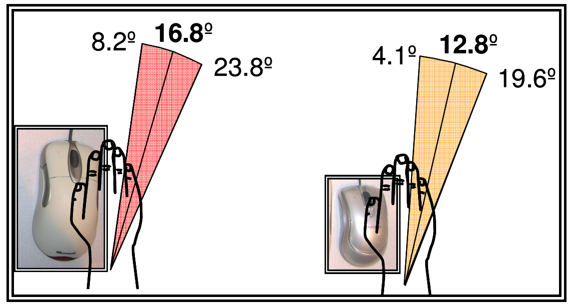


Figure 5: Illustration of wrist posture differences in children between standard and small mouse (n=14)

3.3. Strength and relative force differences

When exerting maximal force with the index finger on a pinch dynamometer, children, on average, were only about 45% as strong as their adult counterparts (see Fig. 6). When forces were expressed as % MVC, children had to apply twice the force of the adults to activate the mouse buttons (see Fig. 6).

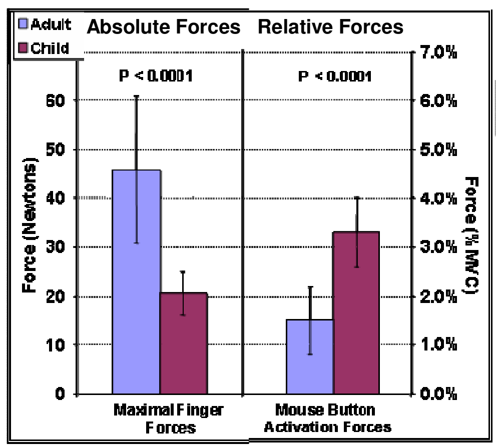


Figure 6: Maximum index finger forces and activation forces for adults (n=14) and children (n=14).

4. Discussion

4.1. Key Findings

The first key finding of this study was that adults and children have dissimilar wrist posture while using a standard mouse. Children had less extension and greater ulnar deviation than adults on standard devices, which may be related to anthropometric differences and the fixed device size. The second key finding of this study was that device size influences wrist posture. Children worked with greater ulnar deviation on the standard mouse versus smaller mouse, suggesting smaller mice may help children maintain a more neutral R/U posture.

Early exposure to current adult-scaled computer equipment may place children at risk of injury both during their formative years and later in life. Both the engineering of input devices and the widespread implementation of computers in every classroom would benefit from a systematic evaluation of child anthropometry, or body and strength measurements, and a characterization of the physical exposures associated with children using adult-sized keyboards and mice. Further exposure characterization may lead to development of hypotheses and methods for future epidemiological studies of associations between children's computer usage and the risk of adverse musculoskeletal health outcomes.

4.2. Study Limitations

The subject order was not randomized; that is, children always completed their tasks before their parents due to their lack of waiting tolerance. Although unlikely, it is possible that some sort of learning by observation bias may have been introduced in adult subjects. A few subjects were not entirely free of musculoskeletal disorders despite study pre-screening. Although no subjects reported discomfort during the experiment, any prior injuries/pain may have reduced the range of motion values for adult subjects. Due to constraints in the height adjustment of the table and chair, a few subjects were working with elbows below table height, which could have introduced a bias in the extension results. Children were restless and sometimes performed extreme movements not related to the task at hand, which could have biased the range of motion data. However, since the data were based on 5th and 95th percentiles rather than the extremes, this effect would be minimized unless the unwanted movements occurred more than 5% of the time.

4.3. Concluding remarks

The preceding data provided evidence of biomechanical differences between adults and children when using computers. Device size affected posture in children, and awkward postures in the upper extremities have been associated with the onset and development of musculoskeletal symptoms [7]. With computer usage among children increasing and with exposures being introduced at increasingly younger ages, greater attention to the design of computer input devices for children is merited as a precautionary measure. The results of this study support continued research efforts aimed at identifying and reducing computer-related health risks in children.

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