GETTING STUCK – THE ANTHROPOMETRY OF YOUNG CHILDREN'S FINGERS

Mic L. Porter

School of Design
University of Northumbria at Newcastle
Newcastle-upon-Tyne
NE1 8ST
mic.porter@unn.ac.uk

An incident occurred in a "Community Infant School" when a child, aged 3+, trapped a finger while playing with a water-bath. The bath was found to conform to the relevant safety standards and this apparent incompatibility acted as the *trigger* for this study. The study sought to obtain anthropometric data, graded by age, of the finger sizes to be found in children living in the North East and attending similar schools to the one which had experienced the incident. This data is outlined and compared with various published sources. Guidance is also given for Designers of consumer and other products with which young children might come into contact.

Introduction and background

A child attending a "Community Infant School" was able to trap a finger in the drain hole of the water-bath with which they had been playing. This was, obviously distressing and painful for the child and of concern to the School. The School referred the matter to the local Trading Standards Department which reported that the bath complied with the relevant safety standards. As this was clearly an undesirable situation, an anthropometric data collection project was started.

The finger length was measured, palm upward, with a metal ruler marked in half millimetres. The larger finger joint diameters were measured with standard UK Jewellers ring "sizer" gauges and a special set made to extended the range downwards and thus accommodate the smallest fingers. The traditional "sizers" are of known diameter and produced in steps of, approximately, 0.2 mm. These will yield more precise data than would be collectable with the commonly used drilled (in 1 mm steps) plastic sheet. Examples of the infant "sizers" are shown (overleaf) in Figure 1. Further details of the measurements techniques adopted can be found in Porter (2000).

The data reported in this paper has been revised from that reported previously (Porter 2000) to include subjects from another geographical area and especially to enlarge the sample taken from the cohort of pupils who would, shortly, transfer, at 7+, to a "Community Junior School".

The "sizer" ring diameter recorded was the smallest through which the finger would, without the application of force, freely pass. During the trial the child was instructed not to push or twist their fingers in an attempt to "make it fit". The experimenter was also vigilant to ensure an unforced measurement and thus avoid the possibility of a trapped finger. The diameter through which the finger would not pass ("just binds") was taken to be one size smaller in diameter.

Figure 1. Examples of the "sizers" produced in the School of Design

Three caveats to the study should be noted. The sample, like the population in the North East was largely *white* and included only about 3% of *visibly non European* children. Ethnic diversity issues have not, therefore, been investigated in this study.

It should also be noted that fingers are ellipsoidal (not circular) in cross section and deformable soft tissue overlies the structure of the finger. Thus care must be taken by a Designer considering non circular holes.

The soft tissue of the finger does deform when forced through a tight but thin hole and, for reasons not yet understood by the author, would appear to "flow" more easily when the ring "sizer" is inserted than when it is removed. No fingers were trapped during the data collection but the possibility was considered and removal strategies planned. It is expected that data collected with a drilled thin plastic sheet would have similar risks.

Results

The anthropometric data collected is available from the author. This database consists of finger lengths and joint diameters for children aged 6 months to 7½ years in six month sets. The data referred to is presented, in table 1.

Table 1. Distal joint diameter and (aged 7 only) finger length; both sexes in mm

Mean(SD)	Thumb	Index Finger	Middle Finger	Ring Finger	Little Finger	Criteria
6 - <8 mth. n = 20	10.1 (1.0)	7.7 (0.4)	8.1 (0.4)	7.8 (0.4)	7.1 (0.3)	"just binds"
30 - <36 mth. n = 20	12.6 (0.4)	10.0 (0.6)	10.3 (0.7)	10.0 (0.5)	8.8 (0.3)	"just passes"
3½ - <4 yrs. N = 51	13.3 (0.8)	10.5 (1.1)	10.7 (0.8)	10.3 (0.8)	9.1 (0.6)	"just binds"
7 - <7½ yrs. n = 31	15.6 (1.0)	12.2 (0.9)	12.4 (0.8)	11.7 (0.7)	10.7 (0.7)	"just passes"
	43.6 (4.2)	51.7 (3.2)	56.7 (3.9)	51.1 (4.6)	43.0 (3.9)	

Discussion and guidance for designers

Nearly twenty five years ago in the USA Snyder *et al* collected and published two sets (1975 and 1977) of anthropometric data for infants and children. Comparison of the data for the middle finger shows that the latter sample generally found slightly smaller values. The data published by the German Standards Institute (DIN 1981) is, where comparisons are possible, slightly larger than Snyder *et al* samples. However, direct comparison is impossible because of variations in the age bands reported. Norris and Wilson (1995) also quote limited details from Steenbekkers (1993) who reports longer, but much thinner fingers than the other samples.

In comparison to these data (table 2 overleaf) this survey is also in general agreement albeit with finger lengths generally larger and diameters generally smaller. Again, however, precise comparisons are often impossible due to the differences in age categories. This sample, however, does contain a greater quantity of hand anthropometric data collected from a sample of children under 7½ years old.

The "European Normalised" British Standard relevant to the safety of toys (BS 1998) has developed from BS 5665 (BS 1988) and the sections referring to holes are, essentially, unchanged. The test appears to be mainly concerned with preventing the child pushing their finger through the hole and coming into contact with something undesirable rather than simply becoming stuck. The Standards specify an "articulated accessibility probe" which comes in two sizes for products to be used by children under 36 months and another for between 36 months and 14 years. The Standard requires that both probes should be applied if the product will be used by all children under 14.

Table 2. Comparative data (both sexes) from published sources (mm)

Dimension and source	Thumb	Index finger	Middle finger	Ring finger	Little finger
Snyder *et al* (1975)					
7 - 9 mth. Length			36 (4)		30 (5)
distal joint diameter			8.4 (0.5)		7.4 (0.5)
31 - 36 mth. Length			45 (4)		33 (3)
distal joint diameter			10 (0.7)		8.6 (0.5)
79 - 84 mth. Length			56 (4)		41 (04)
distal joint diameter			11.9 (0.8)		10.1(0.7)
8 years Length			58 (4)		43 (4)
distal joint diameter			12.2 (0.8)		10.3 (0.7)
Snyder *et al* (1977)					
6 - 8 mth. Length	9.9 (0.7)		8.3 (0.7)		
2 - 3½ yr. Length	36 (4)	41 (4)	44 (4)		
distal joint diameter	12.4 (0.9)	9.6 (0.6)	9.9 (0.6)		
6½ - 7½ yr. Length	47 (4)	52 (3)	58 (4)		
distal joint diameter	15.0 (1.0)	11.7 (0.8)	12.0 (0.9)		
DIN (1981) (All standard deviations estimated from range data)					
3 years Length	37 (2.1)	42 (2.4)		45 (2.7)	36 (2.7)
7 years Length	46 (3.3)	54 (3.3)		55 (3.3)	44 (3.6)
8 years Length	47 (3.6)	55 (3.9)		57 (3.9)	45 (3.9)
Steenbekkeers (1993) (Standard deviations for diameter estimated from range data)					
3 years Length			49 (4)		
7 years Length			59 (4)		
0 - 2 mth. distal joint					6.5 (1.0)
3 - 5 yrs. distal joint					6.6 (0.5)
6 - 8 yrs. distal joint					7 (0.3)

The end of the smaller probe is 5.6 mm in diameter and 44 mm long. This would safely satisfy the data collected in this study. However, it is clear that the larger probe does expose children to the risk of trapped fingers if they are only a little older than 3 years but intent on "exploring". The child whose incident triggered this study fell into this category. For the older age group the data is 8.6 mm diameter and 57.9 mm long. The length standard is acceptable given that children whose fingers are this long will be prevented from insertion due to the hole diameter.

However, the Standard will expose some children to the risk of trapping fingers. For example, the data given in table 1 for mean and standard deviations of the 3½-4 year old child would imply approximately 4% of children risk jamming their Index finger and about 1.75% their ring finger into a hole that would satisfy the Standard. Of course, the risk of being able to jam the little finger is even greater; approximately 20 of that population.

There are two approaches to ensuring that fingers cannot get stuck in orifices or holes. The Index is to ensure that the hole is too small for the finger to penetrate and thus the critical dimension is for the youngest child's smallest finger. The data collected suggests

that the critical hole diameter should be less than 5.9 mm (mean minus four standard deviations). Alternatively a less secure/satisfactory standard would be 6.2 mm diameter (mean minus three standard deviations). (Table 3, below)

Table 3. Data calculated from the means and standard deviations (SD)

	Thumb	Index Finger	Middle Finger	Ring Finger	Little Finger
6 - <8 months					
Mean - 3SD	7.1 mm	6.5 mm	6.9 mm	6.6 mm	6.2mm
Mean - 4SD	6.1 mm	6.1 mm	6.5 mm	6.2 mm	5.9mm
30 - <36 months					
Mean + 3SD	13.8 mm	11.8 mm	12.4 mm	11.5 mm	9.7 mm
Mean + 4SD	14.2 mm	12.4 mm	13.1 mm	12.0 mm	10.0 mm
7 - 7½ years					
Mean + 3SD	18.6 mm	14.9 mm	14.8 mm	13.8 mm	12.8 mm
Mean + 4SD	19.6 mm	15.8 mm	15.6 mm	14.5 mm	13.5 mm

The second, alternative, approach is to ensure that any finger (or the thumb) can pass freely through the hole without the risk of becoming trapped or of scratching against the edge. This general standard would need to be based upon the largest diameter finger on the largest child to be considered. Thus the critical dimension would be the mean plus three standard deviations or the much safer plus four standard deviations. For small items the general guidance is for the under 36 months. For this group a hole diameter of 14.2 mm or 13.8 mm respectively is implied. However, a hole of this diameter will have the potential to trap the fingers and thumbs of some of the older children. In the case of the 7 -7½ age group a 14.2 mm diameter hole can be calculated to be, approximately, equivalent to a 8th percentile thumb joint and thus a potential trap. The 13.8 mm hole could also trap fingers. The diameter of the desirable "clearance" hole for all children (7 -7½) may be calculated to be 18.6 mm (mean plus 3SD) or 19.6 mm (mean plus 4SD).

In the case of this second criterion, a further factor may need consideration from the point of view of safety. Is it possible for a finger inserted in the hole to come to harm from what is behind; either by physical contact or by sufficient proximity to an electrical source that a spark may jump the remaining gap. The length of fingers for the 7 -7½ age group is given in table 1. The longest finger is the middle and consideration of which suggests a clearance between the base of the finger and the risk should be 68.4 mm (mean plus 3SD) or the safer 72.3 mm (mean plus 4SD).

Conclusions

Children whose age is near to the bottom of the 36 month – 14 year range could, potentially, get their fingers caught in holes that met the Standards for which revision would, thus, be desirable. A trapped finger is unlikely to be "life threatening" but will be distressing and, potentially painful.

The mechanism by which soft tissue can roll and "squirm" through very thin objects, such as used in this and other studies, increases this risk and should be investigated

further. It would appear that the flexibility of the soft tissue is different in each direction, generally it is easier to force the finger through the hole than it is to extract it!

The data collected in this study is more complete that that published in other sources and thus should aid the Designer, especially those working on consumer products.

Acknowledgements

Acknowledgement must be made to all the children who agreed to be measured, to their parents/guardians who gave the required permission and to the staff of the schools and nurseries involved in this study. To Derek Anderson, Jewellery Technician, within the School of Design who expertly produced the infant ring "sizers" essential to this data collection exercise and to Katherine Johnston who under took the pilot project.

References

BS, 1989, *BS 5665: Safety of Toys Part 1,Specification for Mechanical and Physical Properties*, (British Standards, London)

BS, 1998, *EN BS 71-1: Safety of Toys Part 1, Mechanical and Physical Properties*, (British Standards, London)

DIN, 1981, *DIN 33402:Body dimensions of people, June 1981*, (Deutsches Institut fur Normung (DIN) e V, Berlin) (Quoted in Norris and Wilson 1995)

Norris B. and Wilson J.R., 1995, *Childata*, URN 95/681, (Consumer Safety Unit, Department of Trade, London)

Snyder, R.G. Spencer M.L. Owings C.L. and Schneider L.W. 1975, *Anthropometry of US Infants and Children (SP394),* (Society of Automotive Engineers(SAE), Washington, DC)

Synder, R.G., Schneider L.W., Owings C.L., Golomb D.H. and Schork M.A. 1977, *Anthropometry of infants, children and youths to age 18 for product safety design*, Report# UM-HSRI-77, (Consumer Product Safety Commission, Washington, DC) (Quoted in Norris and Wilson 1995)

Porter, M.L. 2000, *The Anthropometry of the fingers of Children,* In the proceedings of the IEA2000/HFES Congress, San Diego, (Human Factors and Ergonomics Society, Santa Monica)

Steenbekkers, L.P.A., 1993, *Child development design implication & accident prevention*, No 1 in Physical Ergonomics Series, (Delft University of Technology (TU Delft), The Netherlands)