Requirements for tests of child finger entrapment in European safety standards

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Contents

Executive Summary

This report is a summary of the project ***'Requirements for tests of child finger entrapment in European safety standards'*** carried out by the IOE at the University of Nottingham for ANEC Child Safety WG R&T. The findings of the study are summarised below.

1. The age children begin to explore with their fingers.

Very little literature was found on the specific age at which children begin to explore with the fingers, or how they explore. An observation study was therefore carried out (Work package 5) to better define this. Twenty eight children aged from 5 to 18 months were observed interacting with toys that had been adapted to incorporate test openings. The openings were 14mm diameter, which meant the children could easily pass their fingers into and out of the openings, to meet experimental ethical and safety considerations.

The youngest child to insert a finger into one of the openings was 6 months. Most of the children at this age tended to insert their fingers accidentally i.e. their fingers were either placed or rested at the openings and slipped in, or the fingers slipped in whilst holding or lifting the toys. However, by age 7 months purposeful exploration was observed where the fingers were intentionally inserted into the openings. The first (index) finger tended to be used most for purposeful exploration, although all fingers were inserted into the openings, including the thumb and little finger. In the majority of cases the fingers were inserted up to and past the first joint; this was more common in purposeful exploration but was also observed in accidental finger insertion.

As the test openings were large enough for the younger children to easily move their fingers in and out of the holes, the study probably did not replicate a real life scenario whereby children would have to purposefully push their finger to get it to pass into a smaller opening. As purposeful exploration was observed at around age 7 months, it is hard to determine whether children younger than this would be able to push their fingers into openings as they tended to put their fingers into the openings accidentally. However, there is still a risk of entrapment for the younger child if they fell against a product with an opening, or if the product fell against them, whilst their fingers were near an opening. That is, the absence of purposeful insertion at less than 7 months does not mean that entrapment is not a risk. This study showed that children as young as 6 months are able to explore with their fingers, therefore it is appropriate to conclude that children of 6 months and over should be protected by the requirements for finger entrapment.

2. Requirements for static finger entrapment hazards

A review of anthropometric data and literature on secular trends was carried out and only one new source of children's finger data found, measured in the UK in 1999 (Porter, 2000). Dimensional requirements for static entrapment were therefore defined using this and the major published sources of children's anthropometric data, measured during the 1970s and 1980s (e.g. those in Childata, 1990). There is likely to have been a continued secular trend (increase) in children's body sizes since these data were measured, but it is hard to assess how much this would affect the fingers of very young children. It is likely there has been some increase since the data were collected, but these changes may be within the error margins of data measurements and extrapolations (e.g. 0.5mm).

For all of the dimensional requirements, the 1st and 99th percentile values have been used. These have been calculated from published data. Setting entrapment criteria according to these percentile values means that 98% of the population will be protected (the smallest and largest 1% of the population will be at risk). Decreasing the percentile values, for example to 5th and 95th percentile values, would mean that the proportion of the population that is protected would reduce to 90% of the population. It is therefore recommended that 1st and 99th percentile values are appropriate to use in this instance. The impact on the recommended dimensions if 5th and 95th percentile values were used is given at the end of this summary.

In order to assess the depth requirements for openings, the length of the finger tip is needed (up to the first or distal joint). The only published data on finger tip length are for the middle finger and for children over 2 years of age. Data have therefore been extrapolated in this study to estimate the finger tip length of both the middle and little fingers and for children aged from birth. This study makes recommendations for requirements for static entrapment hazards based on these data and calculations as follows:

MINIMUM DIAMETER REQUIREMENT:
Current requirement [CEN/TR 13387:2004 (E)]: 5 mm for rigid openings/7mm for flexible materials/mesh
Recommendations: No change for round or oval openings. A possible reduction to 3 mm width for slots.
Rationale:
Round/oval openings:
The 1st percentile breadth of the distal (furthest) joint of the little finger for 6-8 month old infants is 5.67mm for males and 4.67mm for females therefore no change is recommended. Data on the diameter of the joint is measured as the maximum size of aperture that *would allow* the joint to pass through; therefore it is recommended that joint breadth should be used.
Slots:
As finger depth at the first joint is less than the breadth or diameter it is suggested that in a slot the finger may be able to pass through a narrower space than in a round opening. 1st percentile depth of the little finger at the distal joint has been estimated in this study as 2.5 mm at 4-6 months old and 2.98mm at 7-9 months old. This means that a slot opening may need to have a minimum width of 3 mm to prevent the little finger entering the opening.   These data should be taken as a guide only due to the assumptions that have been made in their estimation:
i) that there is a linear relationship between finger length and depth
ii) that the little and middle fingers grow at the same rate
iii) that the standard deviation of the breadth of the little finger is similar to the that of the depth.

MAXIMUM DIAMETER REQUIREMENT:
Current requirement: 12 mm
Recommendations: Increase to 14.5 mm to exclude entrapment of the fingers only OR 15.5 mm to exclude entrapment of the thumb.
Rationale:
The 99th percentile *diameter* of the middle joint of the middle finger for 4-4.5 year olds is 14.5 mm (the middle finger is wider than the index finger at that joint and at that age). The diameter in this case is measured as the maximum size aperture through which a finger *cannot* pass, so has been used instead of joint breadth.
The 99th percentile diameter of the thumb for 3.5-4.5 year olds is15.20 mm. (The age groups differ due to the age groups of published data i.e. different sources of data measured different age groups).

MINIMUM DEPTH REQUIREMENT:
Current requirement: 10mm
Recommendations: Decrease to 3.5 mm to protect the little finger OR 6mm to protect the middle finger.
Rationale:
The current requirement of 10 mm would only protect children 3.5 years and older at the 1st percentile value (1st percentile middle finger tip length is 9.3 mm for 3.5-4.5 year old children). The recommendations are based on 1st percentile little finger tip length (3.64 mm) and 1st percentile middle finger tip length (6.2 mm) of children aged 7-9 months.
These data has been estimated based on the following assumptions:
i) the proportional growth in the finger segments is the same for children under 2 years as older children
ii) the ratio of finger tip to overall finger length is the same for children under 2 years as older children

ii) the relationship between the finger tip length and full finger length of the middle finger are the same for the little finger.

3. First review of tests for dynamic finger entrapment hazards

A feasibility trial showed that 3D scanning is a useful technology to produce accurate data on the effects of dynamic entrapment on finger size and shape, The trial demonstrated that the depth of the fleshy part of the finger tip under compression will be far less than the depth or diameter of the joint, which is currently used to set requirements. A recommendation is made that the current requirement for moving parts (CEN 13387:2004) of 12mm will not protect the fleshy part of the finger, and that the minimum requirement for moving parts should be less than 5 mm. Further work is required to specify this dimension further.

Note 1: Consideration of alternative percentile values

The effect of using alternative percentile values on the recommended static entrapment values are presented below:

	1st percentile	**5th percentile**
Minimum diameter requirement (Little finger breadth at distal joint)	5 mm (4.7mm female/5.7mm male)	6 mm (5.4mm female/6.4mm male)

	99th percentile	**95th percentile**
Maximum diameter requirement:		
Thumb (breadth at distal joint)	15.5 mm (15.2 published)	14.1 mm
Middle (finger breadth at middle joint)	14.5 mm	13.77 mm

The 5th/95th percentile values for little and middle finger breadths have been calculated using published data. The 95th percentile value for thumb is reproduced from Table 2. The comparison shows that decreasing the range of children protected from 98% to 90% would mean that the static requirements could change by around 1mm. The minimum width of round opening could increase from 5 to 6 mm and the maximum width requirement could be decreased from around 15.5mm for fingers and 14.5mm for the thumb to around 14mm for fingers and 14mm for the thumb. The figures for depth of openings and for slots have not been calculated at the 5th and 95th percentile levels as this would require repeating the estimations carried out in the study. However, similar changes of between 0.5-1mm could be expected; most likely at the 0.5mm level as the figures are smaller.

1 Introduction

This is the final report on the project ‘Requirements for tests of child finger entrapment in European safety standards’ carried out by the IOE at the University of Nottingham for ANEC Child Safety WG R&T. It incorporates the findings of the two interim reports issued in July and October 2011. The methods and results of the project are presented under topic headings that address the research questions in the project specification, rather than by the work packages undertaken, as some of these overlapped.

2 Review of Current Literature

A comprehensive search of the literature was carried out to: i) identify issues relating to finger entrapment in child care articles and other items ii) review methodology related to research into finger entrapment iii) injury data and iv) to identify stages of development in infants and children in order to understand better potential capabilities (Work package 1).

2.1 Literature on finger entrapment

The current requirements (CEN 13387:2004 (E)) state that no rigid openings should be between 5mm and 12mm unless the depth of the penetration is less than 10mm and openings in mesh and flexible materials should be less than 7mm diameter. There is a paucity of literature in the area of finger entrapment related to the child use and care articles, or in methodologies to test or assess entrapment hazards.

2.2 Injury data

Data reported in the literature mostly refers to the causes of finger entrapment being jammed or crushed in doors. Doraiswamy (1999) reported the following causes of finger injuries:

Table 1: Injury data from Doraiswamy (1999) for finger injuries

Cause	Number	(%)
Jammed/Crushed in opposing surfaces	136	48
Fall	63	22
Hit	31	11
Others	27	10
Cut	26	9
Total	283	

2.3 Child development

The child development literature does not provide information on when an infant may use their fingers to ‘insert’ or ‘poke’ to lead to finger entrapment. However, information relating to general development and reaching and grasping does allow us to understand the ages at which physical movement develops, which may contribute to this risk.

2.3.1 Reaching and object exploration

Lobo and Galloway (2008) report the onset of the ability to reach to be at about 4 months of age. The grasping ability required for sustained oral or manual object exploration does not emerge until after the onset of reaching (Konczak & Dichgans, 1997; Rochat, 1989 reported in Lobo and Galloway, 2008). Infants move their arms often in the period before they begin to reach with and without the presence of objects or people. It is through these spontaneous movements that infants explore the biomechanics of their bodies and the forces acting upon them and gain the motor control required for later object interaction (Bhat, *et al*., 2005; Thelen, 1990; von Hofsten, 1993). After reaching emerges, infants reportedly begin to move their arms with more control, which allows for more purposeful interaction with objects (Bhat *et al*., 2005; Thelen et al., 1993). The onset of reaching also coincides with the time when infants typically begin to assume more varied postural orientations, rolling prone and supine. Better postural control coupled with reaching and grasping ability allows infants to independently explore objects in new ways for sustained periods through mouthing and touching (Adolph *et al*., 2000; Gibson, 1979).

Bushnell (1985) reviewed the literature on the use of vision in reaching and described three phases in its development. In the initial phase, reaching movements were assumed to be visually elicited and were programmed using a primitive mapping between vision and proprioception. These early movements were generally unsuccessful and were described as largely ballistic and uncorrected (these movements are sometimes called “pre-reaches”). A second phase of development was proposed to begin when infants became able to correct their ongoing reaches using the visual error between the target and the hand. This achievement was said to occur at about 4 months-of-age.

Bushnell (1985) proposed a third developmental phase where there was a decreasing reliance on visual feedback of the hand. Bushnell suggested that with practice the infant’s initial command to the arm became more appropriate and corrections became decreasingly necessary. This last phase began at about 8 months-of-age and was an important cognitive event because the reduced attentional demands of reaching freed up capacity that could be used to attend to other important aspects of the situation.

Table 2: Child development: Physical stages (adapted from Robinson, 2008)

Age range	Physical ability/Shift in development
0-3 months	Movement of arms and legs random at 1 month- gradually becomes more purposeful. Prefers lying on back. Emergence (from 3 months) of open handed, broadly directed reaching for objects and begins to bat at objects.
3-8/9 months	Increasing curiosity allied with growing motor and visual coordination. Developing capacity to reach and grasp with hand tending to be shaped to object size by 9 months – coincides with disappearance of grasp reflex between 4 and 6 months. Episode of compulsive reaching between 6 and 9 months and child uses a raking motion to bring objects into the hand – prior to the development of the pincer grasp.
7/8-12 months	Expansion of sensory world through greater mobility and introduction of new tastes, visual and hearing acuity. Can cross midline of body, that is, able to transfer objects from one hand to the other, and thumb/finger pincer grasp develops between 7 and 9 months. Increase in mobility, combines with emergence of simple depth perception in most children by 12 months. Increasing curiosity allied with growing motor and visual coordination.
12-24 months	Increasing mobility and range of movements with integration of movement in near and far space, for example, reach for objects reliably 1-1.5 years. Increase in fine motor control.

3 Assessment of anthropometric data for finger entrapment requirements

3.1 The data

Sources of anthropometric data on children's and infants' finger sizes were reviewed (Work package 2). A summary of the published data according to age and country of origin is shown in Table 3. The full tables of data are presented in Appendix 1, and the sources of the data can be found in the reference section.

Table 3: Anthropometric data on finger size according to age and country of origin

Finger	Joint	Measurement	Age	Country	Publication date
First (index) finger	Distal (furthest) joint	Breadth	3-17 years	Germany	1981
		Diameter*	6 mo - 7 years	UK	2000
			2-19 years	USA(1)	1977
	Middle joint	Breadth	3-17 years	Germany	1981
		Diameter*	6mo - 7 years	UK	2000
Middle finger	Distal (furthest) joint	Breadth	2-10 years	USA(2)	1977
			3-17 years	Germany	1981
		Diameter*	6mo - 7 years	UK	2000
			0-19 years	USA(1)	1977
		Depth	2-10 years	USA(2)	1977
	Middle joint	Breadth	2-10 years	USA(2)	1977
			3-17 years	Germany	1981
		Diameter*	6mo - 7 years	UK	2000
		Depth	2-10 years	USA	1977
	Length	Tip to distal joint	2-10 years	USA	1977
		Whole finger	0-19 years	USA	1977
			2-12	NL	1993
Third (ring) finger	Distal (furthest) joint	Breadth	3-17 years	Germany	1981
Little finger	Distal (furthest) joint	Breadth	0-12 years	NL	1993
			3-17 years	Germany	1981
		Diameter**	0-18 mo	NL	1993
	Middle joint	Breadth	3-17 years	Germany	1981
	Length	Whole finger	3-17 years	Germany	1981
			0-13 years	USA	1975
Thumb	Distal (furthest) joint	Breadth	2-12 years	NL	1993
			3-17 years	Germany	1981
		Diameter*	0-19 years	USA	1977
	Length	Tip to crease	2-4 years	USA	1977
			3-17	Germany	1981

* Defined as 'The maximum diameter of aperture through which the joint ***CANNOT*** pass'

** Defined as 'The maximum diameter of aperture through which the joint ***CAN*** pass'

3.2 Which data to use?

Most published sources of children's anthropometric data were measured between the 1970s and 1980s, (e.g. Snyder et al., 1975, Steenbekkers, 1993). Body sizes have increased over time (often referred to as secular trend), therefore the validity of data measured some time ago can be questioned. The aim of this review was to identify any recent data sources and to assess the validity of the existing major anthropometric sources.

A comprehensive literature search was carried out for both new data sources and information on secular trends. Internet search engines Web of Science and Google Scholar were used to search academic publications and government and commercial databases from 1980 onwards. Search terms included:

- Child*/infant + anthropometr*
- Child*/infant + finger/hand + size/dimension/anthropometr*
- Child*/infant + entrapment
- 3D/scan + anthropometr*

There have been some large scale anthropometric surveys carried out in recent years (e.g. CAESAR), but none contain data on young children or on finger dimensions. However, one recent source of anthropometric data on children's finger sizes was found, measured in the UK in 1999:

Porter, ML, 2000, The anthropometry of the fingers of children. Proceedings of the IEA 2000/HFES 2000 Congress, pp6-27-6-30. The Human Factors and Ergonomics Society.

The survey measured children aged 6 months to 7 years, with a sample size of 20 - 35 children in each 2 or 6 month age group, and presents data on the diameter of the first and middle finger at the distal (furthest) and middle joints. This represents the most recent data on these dimensions.

With regards to the validity of the older data, a full analysis of the validity of the large UK and US datasets in Childata (DTI, 1995) was carried out for the DTI in 2001 (Smith and Norris, 2001). It looked at changes in height and weight in children between 2 and 18 years old, between the 1970s and 1990s. It found that stature had increased, on average, by around 1% and weight by around 7% over that 20 year period. This suggested that circumferential dimensions (such as finger size) may have increased by a similar percentage to body weight. The largest increases were in young adolescents (11-15 year olds), related to when adult eating patterns have become established. The assessment did not include children under 2 years and it may be difficult to relate these findings to young infants (say up to 10 months) when solid food is still being introduced.

A full scale statistical assessment of the possible changes in height and weight in infants is outside of the scope of the study. There is a wealth of literature on infant and childhood weight but the majority is related to nutrition and obesity, and no studies could be found on the changes in weight or dimensions for children under two years that fit the needs of this study. Some recent studies suggest that increases in weight gain in children still continue in Europe (Van den Hurk, 2007 and Rennie, 2005) but others suggest it may have slowed down: Rokholm (2010) reviewed over 50 studies on childhood obesity in 2009 and found that recent increases had stabilised in Europe and the USA since 1999.

Given the lack of definitive literature on how changes in weight may impact on finger sizes, a comparison of the published finger data was carried out. The only data that can be directly compared over time (due to age groups and when they were measured) are the diameter of the distal joint of the middle finger (measured as the largest aperture size through which a finger will not pass), measured by Snyder in the USA between 1975 and 1977 and then more recently Porter in the UK in 1999. The 1st and 99th percentile values were calculated from the published data and are presented for comparison in Table 4. Snyder's data (USA, 1977) is in normal type and Porter's data (UK, 1999) is in parenthesis. As each source measured slightly different age groups the data have been matched as closely as possible and the UK data have been averaged over the 2-3.5 and 3.5-4.5 yrs age bands.

Table 4: Comparison of MIDDLE FINGER distal joint DIAMETER between 1975/7 (USA) and 1999 (UK) (males and females, in mm)

AGE	mean	SD	2.5%ile	97.5th%	1st%ile	99th%ile
0-2 mo	7.2	0.6	6.3	8.1	5.8	8.6
3-5 mo	7.6	0.6	6.3	8.3	6.2	8.99
6-8 mo	8.3 (8.3)	0.7 (0.42)	7.5 (7.0)	9.0 (9.0)	6.67 (7.32)	9.93 (9.28)
9-11 mo	8.9 (9.2)	0.7 (0.55)	7.6 (8.0)	10.0 (10.0)	7.27 (7.92)	10.53 (10.48)
12-15 mo **16-19mo** **(1-1.5 yrs)**	9.0 8.8 (9.2)	0.6 0.6 (0.55)	7.9 7.9 (8.0)	9.7 9.5 (10.0)	7.6 7.4 (7.92)	10.4 10.2 (10.48)
20-23 mo **(1.5-2 yrs)**	9.1 (9.7)	0.8 (0.48)	7.9 (9.0)	10.1 (10.0)	7.24 (8.58)	10.96 (10.82)
2-3.5 yrs	9.9 (10.3)	0.6 (0.9)	8.7 (8.7)	10.8 (12)	8.5 (8.32)	11.3 (12.34)
3.5-4.5 yrs	10.4 (11.4)	0.7 (1.2)	9.1 (9)	11.2 (13.5)	8.77 (8.62)	12.03 (14.19)

(Highlighted text – see below)

Table 4 shows that for the smallest and youngest children at risk (highlighted in red: 1st percentile, 6 to 8 months old), finger diameter increased between the 1970s and 1990s by 0.65 mm (10%). For the oldest and largest children at risk (highlighted in yellow: 99th percentile values, 3.5 to 4.5 years) it increased by 2 millimetres (16%). Finger joint diameters are usually calculated using pre-cut sizers in 1 mm increments (although the UK study used 0.2mm increments and those data are published to one decimal point). Therefore any increments less than 1 mm are difficult to interpret as these are likely to be within measurement error limits.

It is likely therefore, based on this assessment, that there was some increase in finger diameters, between the mid-1970s and 1999. It is possible that this increase has continued since 2000 if there has been a continued secular increase in weight but that it is likely to be close to the confidence limits of the data collection and estimation techniques. Nevertheless, the upper limits of data ranges for requirements should be taken to compensate for any increases.

3.3 Choosing which measurements to use

The relevant data to be used to set static finger entrapment are suggested in Table 5:

Table 5: Anthropometric data to set static finger entrapment requirements.

	Minimum diameter requirement:	**Maximum diameter requirement:**	**Maximum depth at which diameter requirements apply**
Current requirement CEN/TR 13387:2004 (E):	5 mm for rigid openings and 7mm for flexible/mesh	12mm	10mm
Rationale:	To prevent the smallest joint of the smallest finger, of the youngest and smallest child at risk, passing into an aperture	To allow the biggest joint of the largest finger, of the oldest and largest child at risk, to pass into and out of an aperture without getting stuck	The maximum depth of an aperture to prevent the first joint of the smallest finger of the youngest and smallest child at risk entering and getting stuck.
Which finger dimension to use:	The diameter/breadth of the distal joint of the little finger, whichever is the lesser of the two	The diameter/breadth of the middle joint of the index/middle finger, whichever is the greater of the two. The thumb has also been considered in this assessment.	The length of the finger from tip to distal joint of the little or middle finger
What age?	The youngest child at risk of putting their finger into an aperture is determined by the observational work in this study as 6 months	The oldest child protected by the standard under consideration, in this case children up 4 years and 11 months.	The youngest child at risk of putting their finger into an aperture, determined by the observational work in this study as 6 months
Which data?	Smallest child = 1^{st} percentile female value	Largest child = 99^{th} percentile male value	

As none of the data sources present 1^{st} and 99^{th} percentile values all of these data points have been calculated for this study. Where female and male values are available separately these have been used however many sources combine the data for gender.

3.4 Static entrapment – the data

The following section present the data and rationale for the requirements for static entrapment as outlined above (Work package 3).

3.4.1 Minimum width requirement for round or oval openings

Table 6 presents Dutch data published in 1993 for the breadth of the little finger at the distal joint and Table 7 presents the diameter. Diameter is defined as the largest aperture through which the joint *can just pass*. They show that the joint breadth is slightly less than the diameter. Given that diameter values would allow the joint to pass through the aperture, it is recommended that joint breadth should be used to calculate the minimum diameter of round openings. If an age of 6 months is used to set the limit, the minimum size requirement is between **4.7 (females) and 5.7mm (males)** based on this data (highlighted in yellow).

Table 6: LITTLE FINGER distal joint BREADTH (mm)

AGE	mean	Sd	3rd%ile	97th%ile	1st%ile	99th%ile	Sex	Country
0-2mo	7	1	6	8	4.67	9.33	M	NL
	6	1	5	7	3.67	8.33	F	NL
3-5mo	7	1	6	10	4.67	9.33	M	NL
	7	1	5	8	4.67	9.33	F	NL
6-8mo	8	1	6	9	5.67	10.33	M	NL
	7	1	6	9	4.67	9.33	F	NL
9-11mo	8	0	7	8	8	8	M	NL
	7	1	6	9	4.67	9.33	F	NL
12-14 mo	8	0	7	9	8	8	M	NL
	8	1	6	9	5.67	10.33	F	NL
15-18 mo	*	-	-	-	-	-	M	NL
	7	1	7	8	4.67	9.33	F	NL
2 yrs	9	1	8	10	6.67	11.33	M	NL
	9	1	7	11	6.67	11.33	F	NL
3 yrs	10	1	8	11	7.67	12.33	M	NL
	9	1	8	11	6.67	11.33	F	NL
	10	0.61	9	11	8.59	11.41	m/f	D
4 yrs	10	1	9	11	7.67	12.33	M	NL
	9	1	8	10	6.67	11.33	F	NL
	11	0.61	10	11	9.59	12.41	Mf	D

* Sample size of 2 so data excluded

Table 7: LITTLE FINGER distal joint DIAMETER (mm) (largest aperture through which the finger CAN pass)

AGE	Mean	SD	3rd%ile	97th%ile	1st%ile	99th%ile	Sex	Country
0-2mo	7	1	6	9	4.67	9.33	M	NL
0-2mo	6	0	6	7	6	6**	F	NL
3-5mo	7	0	6	8	7**	7**	M	NL
3-5mo	6	1	5	7	3.67	8.33	F	NL
6-8mo	7	0	7	8	7**	7**	M	NL
6-8mo	7	0	6	7	7**	7**	F	NL
9-11mo	7	0	7	8	7**	7**	M	NL
9-11mo	8	1	7	8	5.67	10.33**	F	NL
12-14mo	8	0	7	9	8	8**	M	NL
12-14mo	8	0	7	8	8	8**	F	NL
15-18mo*	-	-	-	-	-	-	M	NL
15-18mo	7	0	7	8	7	7**	F	NL

* Sample size of only 2
** Reported standard deviation (SD) of zero, therefore the SD was calculated from the reported 3rd and 97th%iles

3.4.2 Minimum width requirement for slots

The above requirements are based on an assumption that round or oval openings will force the finger into a shape for which the diameter is an appropriate measurement. Porter (2000) recommends that the extent to which the soft tissue of the finger can 'roll' through openings should be investigated, and that the flexibility of the soft tissue may differ in each direction. There is little evidence on this at present. Slots may require the finger to distort in a different way to a round opening and it maybe that the finger could pass through a slot whose width was equivalent to the depth of the finger. Therefore a comparison was made between the depth and the diameter of the finger. Table 8 presents the depth and diameter for the middle finger at the furthest (distal) joint. It can be seen that depth is generally less than diameter at the 1st percentile value; for instance, for 2.5 to 3.5 year olds the depth at the distal joint is 11.33 mm compared to 13.25 mm diameter (averaged over the age groups 2.5-3 and 3-3.5 years – highlighted in yellow).

Table 8: MIDDLE FINGER distal joint (mm)

AGE (yrs)	mean	SD	1st%ile	99th%ile	Dimension	Country
2.5-3.5 yrs	9	1	6.67	11.33	Depth	USA
2.5-3 yrs	10.3	0.71	8.65	11.95	Diameter	UK
3-3.5 yrs	11.1	1.48	7.65	14.55	Diameter	UK
3.5-4.5 yrs	10	1	7.67	12.33	Depth	USA
3.5-4 yrs	10.9	1.09	8.36	13.44	Diameter	UK
4-4.5 yrs	11.9	1.3	8.87	14.93	Diameter	UK

Given this observation, it was thought of interest to try to calculate the depth of the little finger at the distal joint. This would provide a figure that might be more suitable for use in defining the minimum size of slot openings to prevent the little finger entering an opening. Given that there are no data on the depth of the little finger, this had to be estimated from existing data.   First the ratio of depth to overall length of the middle finger was calculated. This was then used to calculate the depth of the little finger based on its length (Table 9). This ratio is based on two assumptions: i) that there will be linear relationship between finger length and depth, and ii) that the little and middle fingers grow at the same rate. Also, as no standard deviations are available to calculate 1st and 99th percentile values, the standard deviation of the breadth of the little finger was used.

Table 9: Length of the LITTLE FINGER and the estimated DEPTH at the distal joint (mm)

			Depth at distal joint			
AGE (yrs)	Mean finger length	Ratio of depth to finger length *	Mean	SD*	1st %ile	99th %ile
0-3mo	24	18	4.32	1	1.99	6.65
4-6 mo	27	18	4.86	1	2.53	7.19
7-9 mo	29.5	18	5.31	1	2.98	7.64
10-12 mo	29.5	18	5.31	1	2.98	7.64
13-18 mo	29.5	18	5.31	1	2.98	7.64
19-24 mo	31	18	5.58	1	3.25	7.91
2-2.5	33	18	5.94	1	3.61	8.27
2.5-3.5	33.5	18	6.03	1	3.7	8.36
3.5-4.5	35	18	6.3	1	3.97	8.63

*standard deviation of the breadth of the little finger at the distal joint

Table 9 shows that the 1st percentile depth of the little finger at the distal joint has been estimated as 2.98mm at 7-9 months old (highlighted in yellow). This means that a slot opening may need to have a minimum width of **3 mm** to prevent the little finger entering the opening, although these data should be taken as a guide only due to the assumptions that have been made in their calculation.

3.4.3 Maximum width requirement for all openings

Tables 10 and 11 present the breadth and diameter of the middle and first (index) fingers at the middle joints. In this case, diameter is measured as the largest aperture size through which a finger *will not pass*. The data are from the UK, USA and Germany. The tables contain the published percentile values, plus the 1st and 99th percentile values which have been calculated for this study. The data are for a combined male and female population. Comparing middle and index finger diameter at the middle joint shows that the middle and index finger tends to be similar sizes at this joint and the difference is usually less than 0.5 mm. Table 11 shows the breadth at the middle joint for age 2.5 years and over (the only data available) and that at this age the finger breadth is greater than the diameter. However, the diameter represents the size of aperture through which the finger ***cannot*** pass, and is probably the best measurement on which to base the maximum width requirement given the likely compression of the fatty tissue. The requirement for an aperture to protect a 4 year old child from passing the middle joint of the largest finger through is therefore based on the 99th percentile value of the middle joint diameter of the middle finger for 4-4.5 year olds which is **14.5 mm** (highlighted in yellow in Table 10).

Table 10: INDEX/MIDDLE FINGERS: middle joint DIAMETER (mm) (largest aperture size through which a finger will not pass)

AGE	mean	SD	2.5%ile	97.5th%	1st%ile	99th%ile	Finger	Country
6-8 months	9.8	0.91	8	12	7.68	11.92	1st	UK
	10	1.01	8	12	7.65	12.35	Middle	UK
9 - 11mo	10.7	0.51	10	12	9.51	11.89	1st	UK
	10.8	0.5	10	12	9.63	11.96	Middle	UK
1-1.5 yrs	11.4	0.7	10	13	9.77	13.03	1st	UK
	11.5	0.71	10	13	9.84	13.15	Middle	UK
1.5-2 yrs	11.6	0.33	11	12	10.83	12.37	1st	UK
	11.7	0.28	11	12	11.05	12.35	Middle	UK
2-2.5 yrs	11.7	0.38	11	12	10.81	12.58	1st	UK
	11.7	0.31	11	12	10.98	12.42	Middle	UK
2.5-3 yrs	11.8	0.58	11	13	10.45	13.15	1st	UK
	12	0.48	11	13	10.88	13.12	Middle	UK
3-3.5 yrs	11.9	0.64	11	13	10.41	13.39	1st	UK
	12.1	0.4	11	13	11.17	13.03	Middle	UK
3.5-4 yrs	11.5	0.82	10	13	9.59	13.41	1st	UK
	11.8	0.96	10	14	9.56	14.04	Middle	UK
4-4.5 yrs	11.8	0.92	10	14	9.66	13.94	1st	UK
	12.1	1.02	10	14	9.72	14.48	Middle	UK

Table 11: INDEX AND MIDDLE FINGERS: middle joint BREADTH (mm)

AGE	mean	sd	5th%	95th%	1st%ile	99th%ile	Finger	Country
2.5-3.5 yrs	12	1	9	13	9.67	14.33	Middle	USA
3 yrs	13	0.61	12	14	11.59	14.41	Middle	D
	13	1.21	11	14	10.18	15.82	1st	D
3.5-4.5 yrs	12	1	10	14	9.67	14.33	Middle	USA
4 yrs	14	1.21	12	15	11.175	16.82	Middle	D
	14	1.21	12	15	11.18	16.82	1st	D

If the maximum width requirement were to address access by the thumb also, the data in Table 12 should be considered. If the same rationale as for the first/middle finger is applied, i.e. that the diameter should be used rather than the breadth, then the upper limit to exclude the thumb for an age group of 3.5-4.5 years is **15.20 mm** (highlighted in Table 12).

Table 12: THUMB: distal joint DIAMETER (mm) (largest aperture size through which the thumb can't pass)

AGE	mean	SD	5th%ile	95th%ile	1st%ile	99th%ile	Sex	Country
0 -2 mo	8.6	0.8	7.1	9.7	6.74	10.46	MF	USA
3 – 5 mo	9.2	0.8	7.4	10.2	7.34	11.06	MF	USA
6 - 8 mo	9.9	0.7	8.7	10.7	8.27	11.53	MF	USA
9 - 11 mo	10.6	0.8	9.5	11.8	8.74	12.46	MF	USA
12 - 15 mo	11	0.7	8.8	11.7	9.37	12.63	MF	USA
16 - 19 mo	10.7	0.7	9.5	11.7	9.07	12.33	MF	USA
20 - 23 mo	11.4	1	9.6	12.6	9.07	13.73	MF	USA
2-3.5 yrs	12.4	0.9	10.5	13.5	10.30	14.50	MF	USA
3.5-4.5	13.1	0.9	11.1	14.1	11.00	15.20	MF	USA

3.4.4 Maximum depth requirement for all openings

This requirement is based on the length of the finger tip (the distance from the tip to the distal /furthest joint). The only data available on finger tip length is for the middle finger, and for children aged over 2.5 years (see dimension 9 in the Appendices). The 1st percentile finger tip length for children age 2.5-3.5 years is 8.3 mm, increasing to 9.3 mm at age 3.5-4.5 years. This suggests that the current requirement of 10mm depth of openings would not protect children aged 2.5 years old, and would probably only just protect children aged over 4 years. In order to better inform the requirement for depth of openings, the finger tip length of younger children for both the little and middle finger have been estimated. Middle finger tip length for young children is calculated first as the data for these are available for older children. Little finger data is then calculated. Figure 1 shows the sequence chart of the mean values of the full length of the middle finger, the finger tip and distance between the two joints for USA male and female children (based on data from Snyder, 1977).

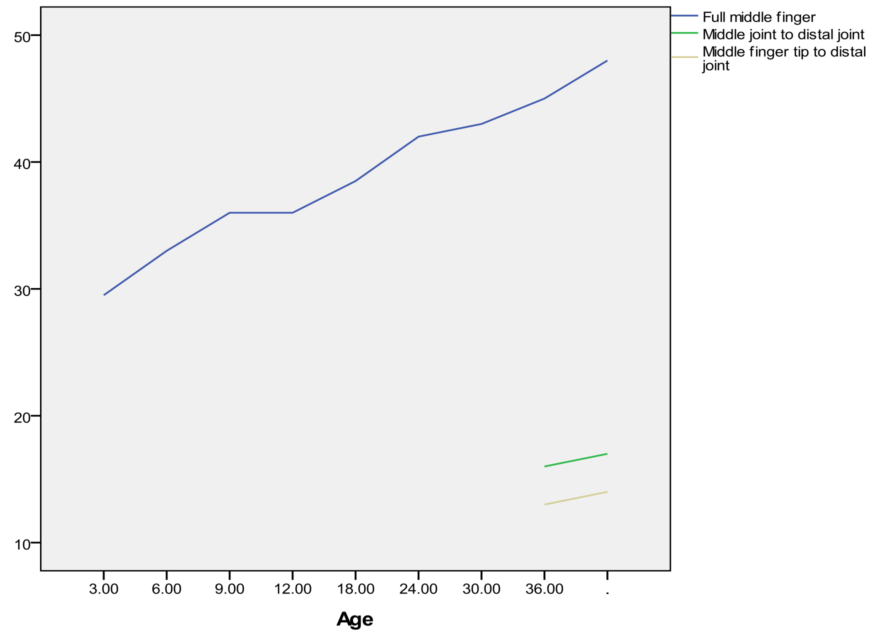


Figure 1: The length of full middle finger, the finger tip (tip to distal joint) and the distal to middle joint for USA male and female children in millimeters (Snyder, 1977)

Finger length shows a linear growth, therefore it is possible to develop a regression model to be able to provide an estimate of the length of the finger tip for children younger than 2.5 years. There are two ways to compute these values, which also allow the data to be validated.

Method 1 uses the change in the full finger length between each subsequent age group (i.e. the growth) for children aged 0-42 months (using data from Snyder 1977) and applies this difference to the finger tip. This is based on the assumption that growth in the overall finger length will be reflected in the same rate of growth in the finger tip. For example, Table 13 shows that the growth in overall finger length between 0-3 and 4-6 months is 10.6. The results are shown in Table 13 (mean values), Table 14 (1st percentile) and Table 15 (99th percentile).

Table 13: Calculation of mean MIDDLE FINGER tip length in mm (Method 1)

Age	Mean middle finger length	% growth in finger length between age groups	Mean finger tip length
0-3mo	29.5	10.6%	8.94
4-6 mo	33	8.3%	9.75
7-9 mo	36	0	9.75
10-12 mo	36	6.5%	10.43
13-18 mo	38.5	8.3%	11.38
19-24 mo	42	2.3%	11.65
2-2.5 yrs	43	5.5%	12.32
2.5-3.5yrs	45.5	5.2%	13
3.5-4.5 yrs	48	5.9%	13.39

Table 14: **Calculation of 1st percentile MIDDLE FINGER tip length in mm (Method 1)**

Age	1st %ile middle finger length	% growth in finger length between age groups	1st %ile finger tip length
0-3mo	20.2	14.8	5.11
4-6 mo	23.7	11.2	5.75
7-9 mo	26.7	4.2	6.00
10-12 mo	27.85	11.7	6.79
13-18 mo	31.5	3.6	7.05
19-24 mo	32.7	6.2	7.51
2-2.5 yrs	34.85	8.13	8.18
2.5-3 .5 yrs	37.93	1.94	8.34
3.5-4.5 yrs	38.7	7.2	9.34
4.5-5.5 yrs	41.68		

Table 15: **Calculation of 99th percentile MIDDLE FINGER tip length in mm (Method 1)**

Age	99th %ile middle finger length – calculated data	% growth in overall finger length between age groups	99th % ile finger tip length
0-3mo	38.82	8.27	13.04
4-6 mo	42.32	6.62	13.96
7-9 mo	45.32	-2.64	13.60
10-12 mo	44.16	2.93	14.02
13-18 mo	45.5	11.36	15.81
19-24 mo	51.32	-0.32	15.76
2-2.5 yrs	51.16	3.61	16.35
2.5-3.5 yrs	53.08	7.41	17.66
3.5-4.5 yrs	57.32	4.97	18.66
4.5-5.5 yrs	60.32		

Method 2 uses the percentage of finger tip to overall finger length for each age group in the 2.5 years-3.5 years age groups (the only age for which all data are available). The same percentage was then assumed for younger children (hence the data in brackets in Tables 16, 17 and 18). This is based on the assumption that the proportion of the finger tip to the overall finger length is the same for children under 2.5 years as it is for children over 2.5 years. These results are shown in Table 16 (mean values), Table 17 (1st percentile) and Table 18 (99th percentile).

Table 16: **Calculation of mean MIDDLE FINGER tip length in mm (method 2)**

Age	Mean middle finger length	% difference between length of finger and finger tip	Mean finger tip length
0-3mo	29.5	(29.16)	8.60
4-6 mo	33	(29.16)	9.62
7-9 mo	36	(29.16)	10.5
10-12 mo	36	(29.16)	10.5
13-18 mo	38.5	(29.16)	11.23
19-24 mo	42	(29.16)	12.25
2-2.5 yrs	43	29.16	12.54
2.5-3.5 yrs	45.5	29.16	13
3.5-4.5 yrs	48	29.16	14
4.5-5.5 yrs	51		

Table 17: **Calculation of 1st percentile MIDDLE FINGER length in mm (Method 2)**

Age	1st %ile middle finger length	% difference between length of finger and finger tip	1st %ile finger tip length
0-3mo	20.18	(24)	4.84
4-6 mo	23.68	(24)	5.68
7-9 mo	26.68	(24)	6.40
10-12 mo	27.85	(24)	6.68
13-18 mo	31.51	(24)	7.56
19-24 mo	32.68	(24)	7.84
2-2.5 yrs	34.85	24	8.36
2.5-3.5 yrs	37.92	24	8.34
3.5-4.5 yrs	38.68	24	9.34
4.5-5.5 yrs	41.68		

Table 18: Calculation of 99th percentile MIDDLE FINGER tip length in mm (Method 2)

Age	99th %ile middle finger length	% difference between length of finger and finger tip	99th &ile finger tip length
0-3mo	38.82	(32)	12.42
4-6 mo	42.32	(32)	13.54
7-9 mo	45.32	(32)	14.50
10-12 mo	44.16	(32)	14.13
13-18 mo	45.49	(32)	14.56
19-24 mo	51.32	(32)	16.42
2-2.5 yrs	51.16	32	16.37
2.5-3.5 yrs	53.07	32	17.66
3.5-4.5 yrs	57.32	32	18.66
4.5-5.5 yrs	60.32		

Comparison of the two methods of calculating the finger tip data is shown in Table 19. It shows a small deviation and it shows that these values can be used to provide a reliable estimation.

Table 19: Comparison of the calculated data for MIDDLE FINGER tip length (mm)

Age	Mean		1st %ile		99th %ile	
	Method 1	Method 2	Method 1	Method 2	Method 1	Method 2
0-3mo	8.94	8.60	5.11	4.84	13.04	12.42
4-6 mo	9.75	9.62	5.75	5.68	13.96	13.54
7-9 mo	9.75	10.5	6.00	6.40	13.60	14.50
10-12 mo	10.43	10.5	6.79	6.68	14.02	14.13
13-18 mo	11.38	11.23	7.05	7.56	15.81	14.56
19-24 mo	11.65	12.25	7.51	7.84	15.76	16.42
2-2.5 yrs	12.32	12.54	8.18	8.36	16.35	16.37
2.5-3.5 yrs	13	13	8.34	8.34	17.66	17.66
3.5-4.5 yrs	13.39	14	9.34		18.66	18.66

The average of the two estimations for each value were therefore used. Table 20 shows that the estimated 1st percentile finger tip length of the middle finger for the lower age limit at risk (7-9 months) is **6.2 mm** (highlighted in yellow).

Table 20: **Comparison of the estimated and published MIDDLE FINGER tip length (mm) for USA males and females**

AGE	SD	Mean	1st% ile	99th% ile
0-3mo		8.77	4.98	12.73
4-6 mo		9.69	5.72	13.75
7-9 mo		10.13	6.20	14.05
10-12 mo		10.47	6.73	14.08
13-18 mo		11,31	7.31	15.19
19-24 mo		11.95	7.68	16.09
2-2.5 yrs		12.43	8.27	16.36
2.5-3.5 yrs	(2)	13 (13)	8.34 (8.3)	17.66 (17.7)
3.5-4.5 yrs	(2)	13.70 (14)	9.34 (9.3)	18.66 (18.7)

( ) = published data

3.5 Calculation of little finger tip length

However, maximum depth requirements for openings should probably be based on the length of the little finger tip. Middle finger tip length has probably been used previously as these were the only data available. The length of the little finger tip has therefore also been calculated.

In order to calculate the length of the little finger tip, similar extrapolation techniques were used as for the middle finger. However, whilst finger tip data for the middle finger were available for older children (2 years above) there are no data for the little finger. Therefore, the ratio of finger tip length to overall finger length for the middle finger were assumed to be the same for the little finger, and this was used to calculate little finger tip length from the available data on overall little finger length (Table 21).

Table 21: **Calculation of the mean length of the LITTLE FINGER tip (mm)**

AGE (yrs)	Middle finger length	Middle finger tip length	Ratio of finger tip to finger length (middle finger)	Ratio of middle finger length to little finger	Little finger length	Little finger tip length
0-3mo	29.5	8.76985	0.297283	0.813559	24	7.134793
4-6 mo	33	9.6864	0.293527	0.818182	27	7.925236
7-9 mo	36	10.1238	0.281217	0.819444	29.5	8.295892
10-12 mo	36	10.46234	0.290621	0.819444	29.5	8.573308
13-18 mo	38.5	11.3008	0.293527	0.766234	29.5	8.659055
19-24 mo	42	11.94652	0.284441	0.738095	31	8.817667
2-2.5 yrs	43	12.43086	0.28909	0.767442	33	9.539961
2.5-3.5 yrs	45.5	13	0.285714	0.736264	33.5	9.571429
3.5-4.5 yrs	48	14	0.291667	0.729167	35	10.20833
4.5-5.5 yrs	51					

Using the data in Table 21 above, the 1st and 99th percentile values of the little finger tip were calculated, as shown below in Table 22. Based on these calculations, the maximum depth of openings to prevent the little finger of the smallest child entering an opening past the distal joint is around 3.5 mm (highlighted in yellow).

Table 22 : Estimated length of the LITTLE FINGER tip (mm)

AGE (yrs)	Mean	SD	1st %ile	99th %ile
0-3mo	7.13	2	2.48	11.795
4-6 mo	7.93	2	3.27	12.59
7-9 mo	8.30	2	3.64	12.96
10-12 mo	8.57	2	3.91	13.23
13-18 mo	8.66	2	3.99	13.32
19-24 mo	8.82	2	4.16	13.48
2-2.5	9.54	2	4.88	14.20
2.5-3.5	9.57	2	4.91	14.23
3.5-4.5	10.21	2	5.55	14.87
4.5-5.5				

4 First review of tests for dynamic entrapment

Finger entrapment in a moving part of a product can cause various forms and levels of injuries. Entrapment scenarios can be grouped into scissoring, pinching and compressing entrapments. The force, direction and the weight of the moving parts during the entrapment define the severity of the injury. Work package 4 aimed to examine requirements for dynamic finger entrapment in the light of possible new test methods. It is worth noting that this work package aimed to assess the feasibility of various test methods and not to derive confirmed figures and recommendations.

Most work on hand anthropometry and entrapment has been limited to one dimensional data. Three dimensional scanning of body parts offers an alternative to the standard body measurement methods. These systems allow body surfaces (whole or part) to be digitised and provide extremely accurate reference points and dimensions compared to traditional physical measurement techniques. They also allow detailed investigation of dynamic scenarios (e.g. measurement of body parts under entrapment) which would not be possible with traditional methods. It was decided to investigate the applicability of 3D scanning technology to dynamic finger entrapment scenarios. 3D scans would be used to assess how the soft tissue of the finger behaves under entrapment and whether this would be a way to better inform the dynamic entrapment requirements to minimize damage to the soft tissue.

4.1 Preliminary anthropometric data collection using the 3D scanner

An investigation into the applicability of 3D scanning to assess the effects of dynamic entrapment scenarios on the fingers was undertaken. The aims were to:

- assess the feasibility of scanning technology
- provide sample data on the effects of an entrapment scenario on the tip of the finger, thereby assessing the appropriateness of current dynamic entrapment requirements.

A Faro Gage scanner was used for the purpose of this study (Figure 2). This is a laser scanner with a portable arm with up to 0.018 mm accuracy.

Figure 2: FARO GAGE scanner -taken from www.faro.com

A compression/pinching entrapment scenario was selected for simulation, as this was the easiest scenario to simulate with the scanner. The tip of the middle finger was trapped from the end of the finger back to near the nail bed, a distance of 9mm. The length of the finger trapped was kept constant in order to assess what happened to the finger under increasing pressure of entrapment.

It was not possible to carry out the simulations with children due to ethical requirements and the difficulty of a young child holding a posture for the required scanning time. The scenario was instead simulated with a 27 year old female. Entrapment was simulated using two metal surfaces (part of a stapler). The shape of the finger whilst trapped was scanned with a 3D scanner. The scanner was calibrated in a 3 hour pilot study. Scanning is a very time consuming process (one scan takes approximately 2 hours) therefore a casting mould was needed to hold the participant's hand motionless during the scanning. Figure 3 shows the hand of the participant rested on the casting mould while being scanned.

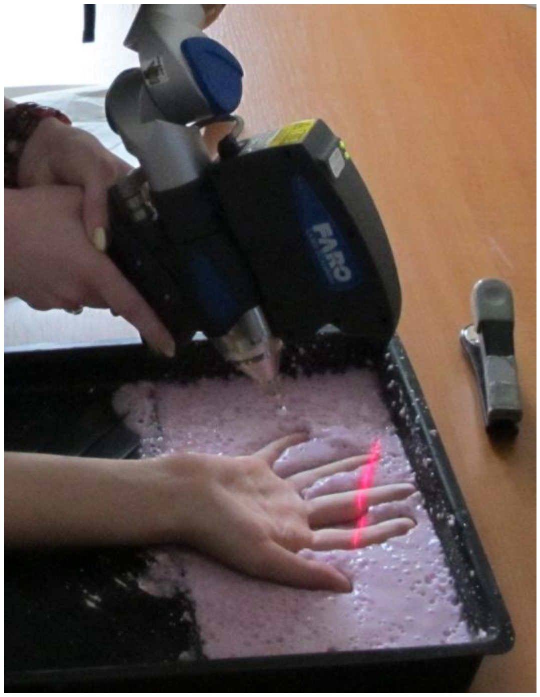


Figure 3: The hand of the participant during scanning

A stapler was used to simulate a pinching/compression entrapment. The finger was trapped between the two metal edges at the rear of the stapler (X). The stapler has one moving part ('A' in Figure 4) which moves against a fixed surface ('B' in Figure 4). The angle between these two parts was measured. The angle in which surface 'A' moves determines the size of the entrapment at point X (i.e. the wider the angle of movement the smaller the size of the space available at the entrapment point).

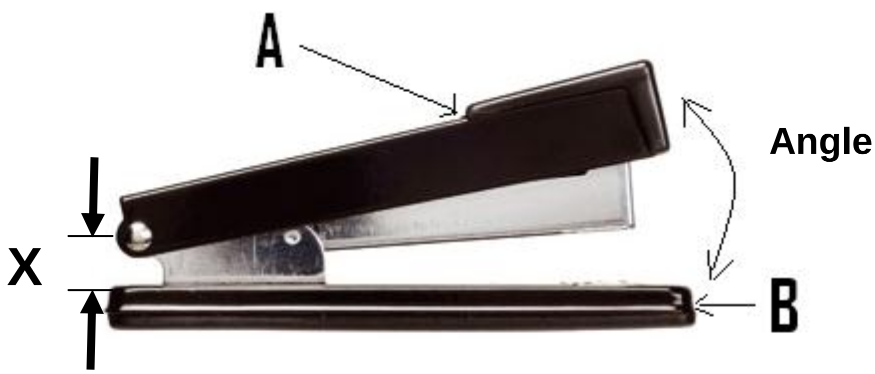


Figure 4: Stapler

In order to explore the effectiveness of 3D scanning, the hand of the participant was scanned in three different conditions:

1. 30° angle at the front of the stapler
2. 50° angle at the front of the stapler
3. 90° angle at the front of the stapler

The data collected were then transferred into a 3D viewer (3D-Tool ™) and the dimensions of the distal joint that was trapped under each of the conditions were measured. Figure 5 shows an example of the 3D scanned distal joint while it is entrapped in the stapler (condition '3' with the stapler at 90 degrees).

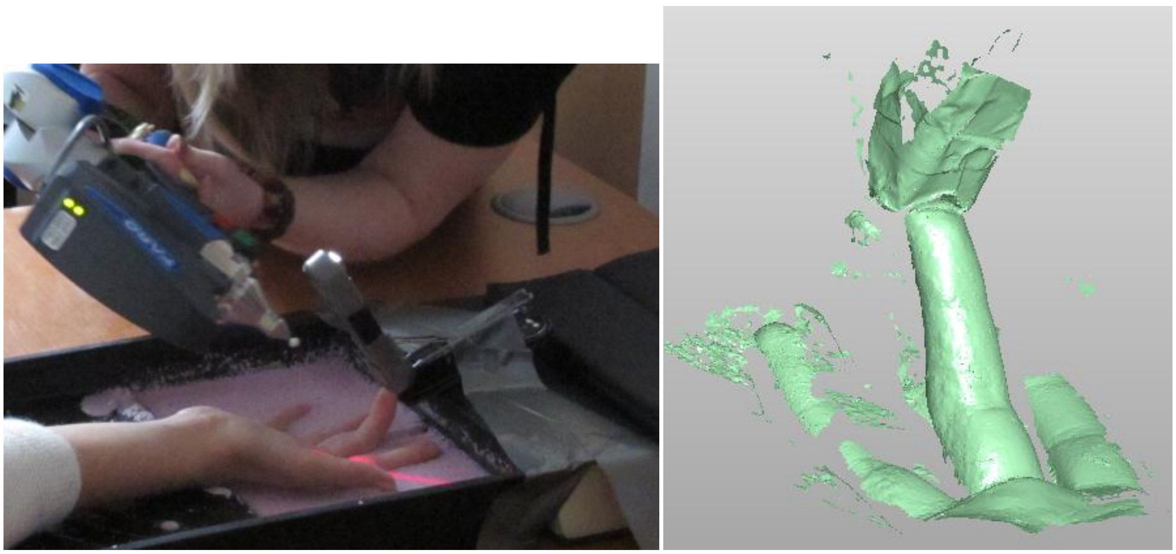


Figure 5: 3D model of the finger entrapped in the stapler

4.2 Findings

This section presents the findings of the 3D scanning. Table 23 shows the breadth (mm) of the middle finger in each of the conditions i.e. with the finger under increasing compression as the angles between 'A' and 'B' increase. The breadth was measured at 9 mm from the end of the finger. The findings suggest that, as one would expect, the breadth of the finger tip at the point of entrapment (the fleshy nail bed) increases as the compression increases. For every 20° increase in the angle, the breadth of the finger tip (at the 9mm point) was increased by 3%.

Table 23: Breadth of the finger measured at 9mm from the finger tip, for each angle of compression (compression increases as the angle increases)

Angle	Breadth (mm)
30°	13.93
50°	14.15
90°	15.12

The feasibility trial shows that as the breath of the fleshy part of the finger tip increases, the depth of the finger at that point will therefore decrease (as the finger is compressed).

Current dimensional requirements for moving parts (CEN 13387:2004) state parts should not close to less than 12mm. This is likely to be based on data available at the time for the diameter of the middle finger at the middle joint for children 6-8 months (Table 10 earlier). However, the minimum requirement for rigid openings is currently 5mm. In order to protect the smallest finger of the smallest child, the dynamic requirements should be in line with this. However this is likely to be based on diameter of the distal joint. This feasibility study demonstrates that the fleshy part of the finger tip is less than that, and will be reduced under compression. It is suggested therefore that the minimum requirement for moving parts should be less than 5 mm but that further work is required to specify this dimension further.

4.3 Evaluation of the test method

3D technologies facilitate accurate and extensive anthropometric data collection. This study produced very accurate dimensional data on the finger under a dynamic entrapment scenario that would not be accessible through normal anthropometric or 2D studies. This study only tested one form of dynamic entrapment, but the 3D scanning technology would be able to model other interactions and entrapments and have a better understanding of the features that can affect the severity of an entrapment in a simulated environment. This would be a good focus for further studies of entrapment. However, despite its great potential, limitations include the time and cost to conduct the scanning process.

5 Observational Study

The aim of the observational study was to give insight into the behaviour young children exhibit which may lead to finger entrapment. Twenty-eight children aged 5 to 18 months were observed to identify the age at which children begin to explore objects with their fingers, when they insert fingers into openings, which finger(s) they use and how.

5.1 Observational Protocol

Ethical approval for the research study was granted by the University of Nottingham's Faculty of Engineering Research Ethics Committee. In order to observe children in as naturalistic setting as possible children were observed in the home, within childcare settings and whilst attending parent and toddler play groups.

The protocol allowed for the differences in the physical abilities of the children, for example some children were sitting, and others crawling or walking.

5.2 Apparatus and task

Three off-the-shelf toys were adapted to incorporate openings of 14mm diameter; this size of opening was used to ensure safety of the children. The toys were selected to be representative of the type of toys commonly used by the age groups targeted, as shown in Figure 6.

Children were presented with each of the toys in turn, one toy at a time. The interaction with the openings was then recorded by the observer (Appendix 2).

Figure 6: Toys used in observational study

The level to which the finger is inserted was recorded, in the following categories:

Grade of finger insertion	Details
1	Finger tip only inserted
2	Finger tip inserted but excluding first joint (knuckle)
3	First finger joint inserted
4	Finger inserted past first joint
5	Finger inserted past first joint with force

5.3 Results of observational study

Twenty eight children, aged from 5 to 18 months (mean: 10.5 months; SD: 3.75) were observed, 12 male and 16 female. Sixteen children were observed in a nursery setting, 8 at a playgroup and 4 in the home.

Seventeen children were observed inserting their fingers in the opening within the ball, (accidentally and intentionally), 10 in the book and 13 in the activity panel. The youngest child to insert their fingers was 6 months, the oldest 18 months (number of each age shown in table 24). Eight children played with the ball without inserting their finger and 10 the book and activity panel. Table 25 shows the recorded number of insertions and observed play with no insertions. In Table 26 the ages of the children are presented according to whether they inserted a finger, played but did not insert and did not play.

Table 24: Age of children observed

Age in months	Number of children
5	1
6	3
7	4
8	1
9	4
10	3
11	2
12	2
13	1
14-18	7

Table 25: Number of children inserting fingers, playing with toy and not inserting fingers

Toy	Insertion	Play but NO insertion	No play
Ball	17 (60%)	8 (29%)	3 (11%)
Book	10 (36.5%)	10 (36.5%)	8 (27%)
Activity Panel	13 (46%)	10 (36.5%)	5 (18%)

Table 26: Age of children in months (and no. of children in brackets) that either inserted a finger/played with toy but didn't insert a finger / didn't play with each toy

Toy	Insertion	Play but NO insertion	No play
Ball	6 7 (x3) 8 9 (x3) 10 (x3) 11 (x2) 15 16 (x2) 17	5 6 7 (x2) 9 15 18	12 13 14
Book	6 9 10 (x2) 11 12 13 15 16 17	5 6 (x2) 7 (x3) 9 10 12 18	7 8 9 (x2) 11 14 15 16
Activity Panel	6 7 8 9 10 11 (x2) 12 14 15 16 (x2) 18	5 6 7 9 (x2) 10 15 17 18	7 9 12 13 15

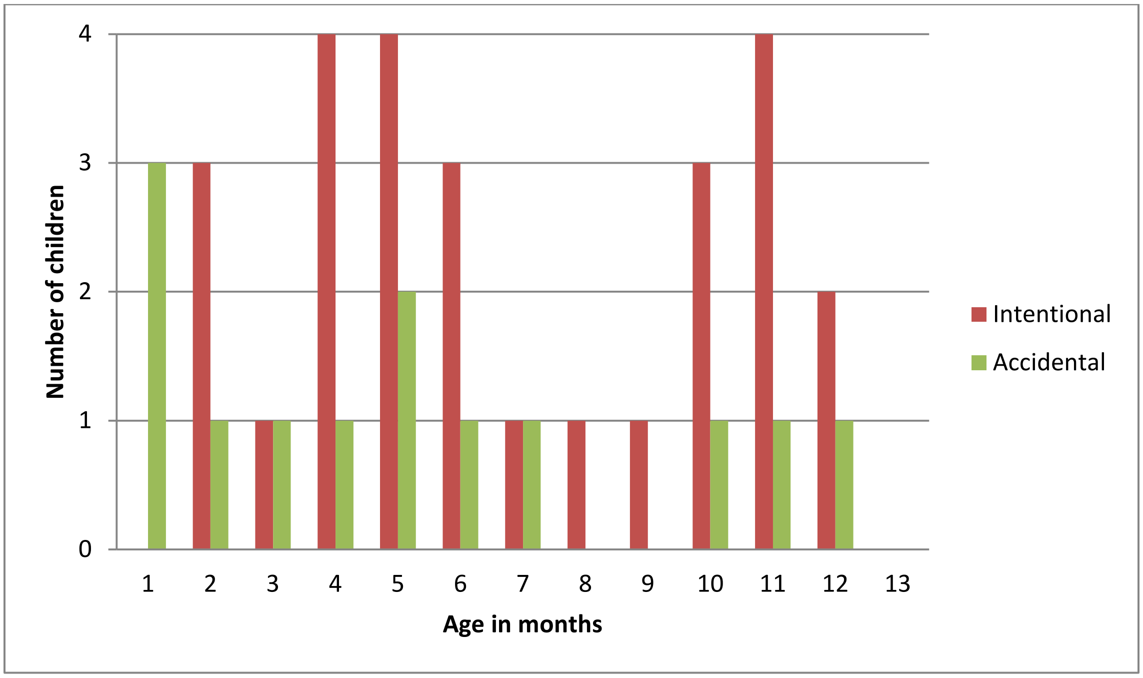
Table 27 shows the ages of the children according to intentional and accidental insertion. This shows that 6 month olds were observed accidentally inserting their fingers. At 7 months the insertion is intentional.

Of the 17 children inserting fingers into the ball, 14 (82%) did so intentionally and 3 (18%) accidentally. Of the 10 children observed inserting fingers into the book, 8 (80%) were intentional and 2 accidental (20%). For the activity panel, 5 (39%) of the children intentionally put their fingers in the openings and 9 (69%) of the children accidentally (1 child both). Figure 7 shows graphically the number of children who inserted intentionally and accidentally at each age.

Table 27: Ages of children in months that inserted a finger in an opening according to whether or not it was intentional or accidental

Toy	Intentional Insertion () indicates number if more than 1 child	Accidental insertion
Ball	7 (2) 8 9 (2) 10 (3) 11 (2) 15 16 (2) 17	6 7 9
Book	9 10 11 12 13 15 16 17	6 10
Activity Panel	7 9 14 15 16	6 8 10 11 (2) 12 15 16 18
All toys	7 (3) 8 9 (4) 10 (4) 11 (3) 12 13 14 15 3 16 4 17 2	6 (3) 7 8 9 10 (2) 11 12 15 16 17 18

Figure 7 Age of children according to intentional and accidental insertion

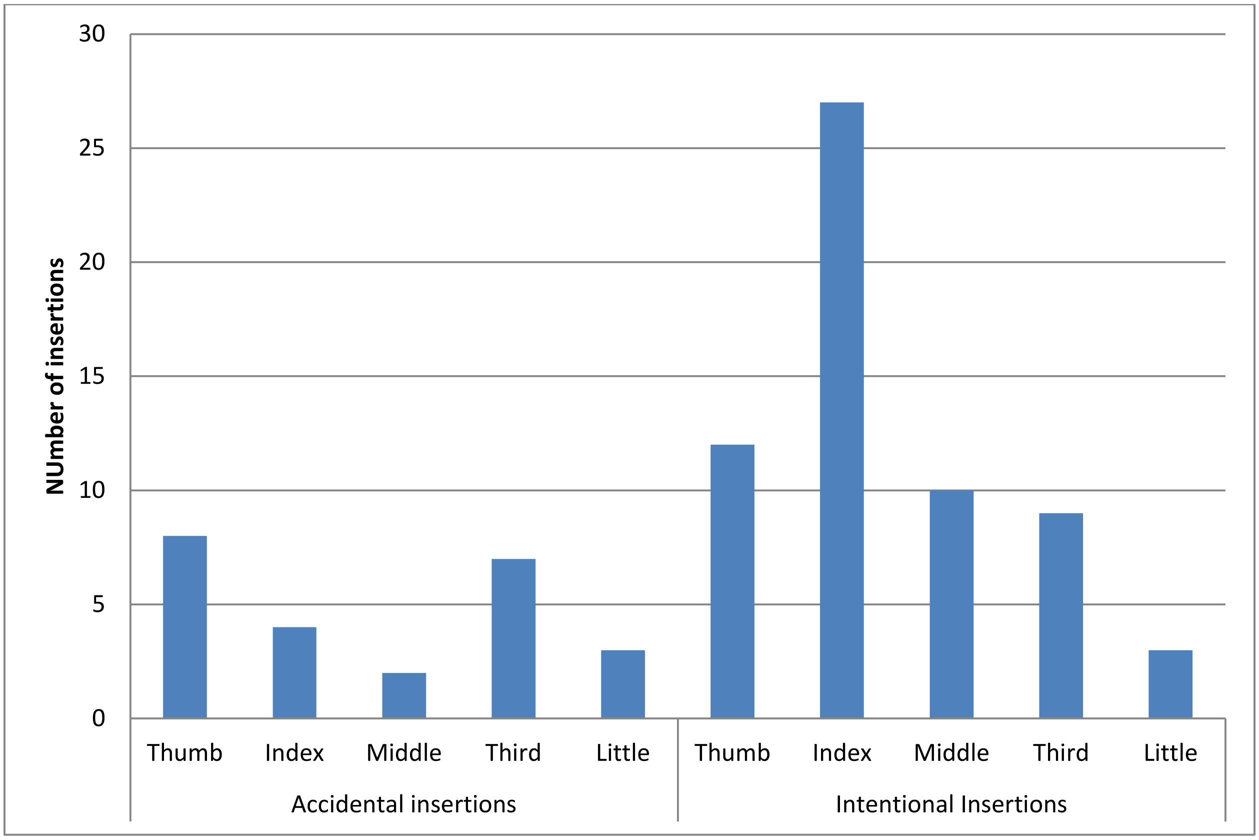


Twenty four accidental insertions were observed and 61 intentional insertions. Table 28 presents the fingers used for insertions (these are combined for both hands) for all toys and which illustrates that there were more intentional insertions than accidental for all but the little finger. The thumb was accidentally inserted most frequently (8) and the third finger (7) perhaps because of their use in grasping items. For intentional insertions the index finger was observed to be most frequently inserted (27). These results are shown graphically in Figure 8.

Table 28 : Occurrences of insertion by finger for all toys (combined for all toys)

	Total insertions	Finger	Number of insertions (both hands)
Accidental insertions (all toys)	24	Thumb Index Middle Third Little	8 (33%) 4 (17%) 2 (8%) 7 (29%) 3 (13%)
Intentional insertions (all toys)	61	Thumb Index Middle Third Little	12 (20%) 27 (44%) 10 (16%) 9 15%) 3 (5%)

Figure 8: Number of accidental and intentional insertions for each finger



In Table 29 the number of insertions for each finger is shown, for both intentional and accidental insertions for each toy (see also Figures 10 and 11). The ball was subject to most intentional insertions. In Table 30 the degree of insertion for all toys are shown and this is shown graphically in Figure 9.

Table 29: Occurrences of insertion by finger for each toy

	Total insertions	Finger	Number of insertions (both hands)
Ball Accidental insertions	6	Thumb Index Middle Third Little	1 3 1 1 0
Ball Intentional insertions	29	Thumb Index Middle Third Little	8 11 5 4 1
Book Accidental insertions	2	Thumb Index Middle Third Little	0 0 1 1 0
Book Intentional insertions	13	Thumb Index Middle Third Little	3 9 0 1 0
Activity Panel Accidental insertions	16	Thumb Index Middle Third Little	7 1 0 5 3
Activity Panel Intentional insertions	19	Thumb Index Middle Third Little	1 7 5 4 2

Table 30: Degree of insertion (all toys totalled)

Finger	Degree to which inserted	Accidental insertions	Intentional insertions
Thumb	tip only inserted	5	0
	tip inserted not as far as first joint	0	1
	joint inserted	2	8
	inserted past first joint	1	2
	inserted past first joint with force	0	1
First (index) finger	tip only inserted	1	1
	tip inserted not as far as first joint	1	2
	joint inserted	2	12
	inserted past first joint	0	8
	inserted past first joint with force	0	4
Middle finger	tip only inserted	0	2
	tip inserted not as far as first joint	1	0
	joint inserted	1	5
	inserted past first joint	0	1
	inserted past first joint with force	0	2
Third (ring) finger	tip only inserted	2	0
	tip inserted not as far as first joint	2	1
	joint inserted	3	4
	inserted past first joint	0	2
	inserted past first joint with force	0	2
Little finger	tip only inserted	0	0
	tip inserted not as far as first joint	2	0
	joint inserted	1	2
	inserted past first joint	0	1
	inserted past first joint with force	0	0

For intentional insertions of the thumb, 92% (11) of the insertions resulted in the joint being inserted or inserted past the joint, for the index finger 89% (24), the middle finger 80% (8), the third finger 89% (8) and the little finger 100% (3).

The index finger was inserted most frequently with the joint inserted (12 occurrences) and the finger inserted past the joint (8 occurrences) and inserted with force (4 occurrences). The thumb joint was inserted on 8 occurrences, the middle finger 5, third finger 4 and little finger 2. For each finger the most observed occurrences involved the joint being inserted.

For accidental insertions of the thumb the tip only was inserted for 63% of insertions (5), for the index finger 50% (2), the middle finger 50% (1), the third finger 57% (4) and for the little finger 67% (2).

This suggests where the insertions were intentional the children were more likely to insert the fingers further and where the insertion is accidental the finger is not inserted so far. In fact we can see from table 30 that for accidental insertions only the thumb was inserted past the joint on one occasion.

Figure 9 Degree of accidental and intentional insertions for all fingers (all toys totalled)

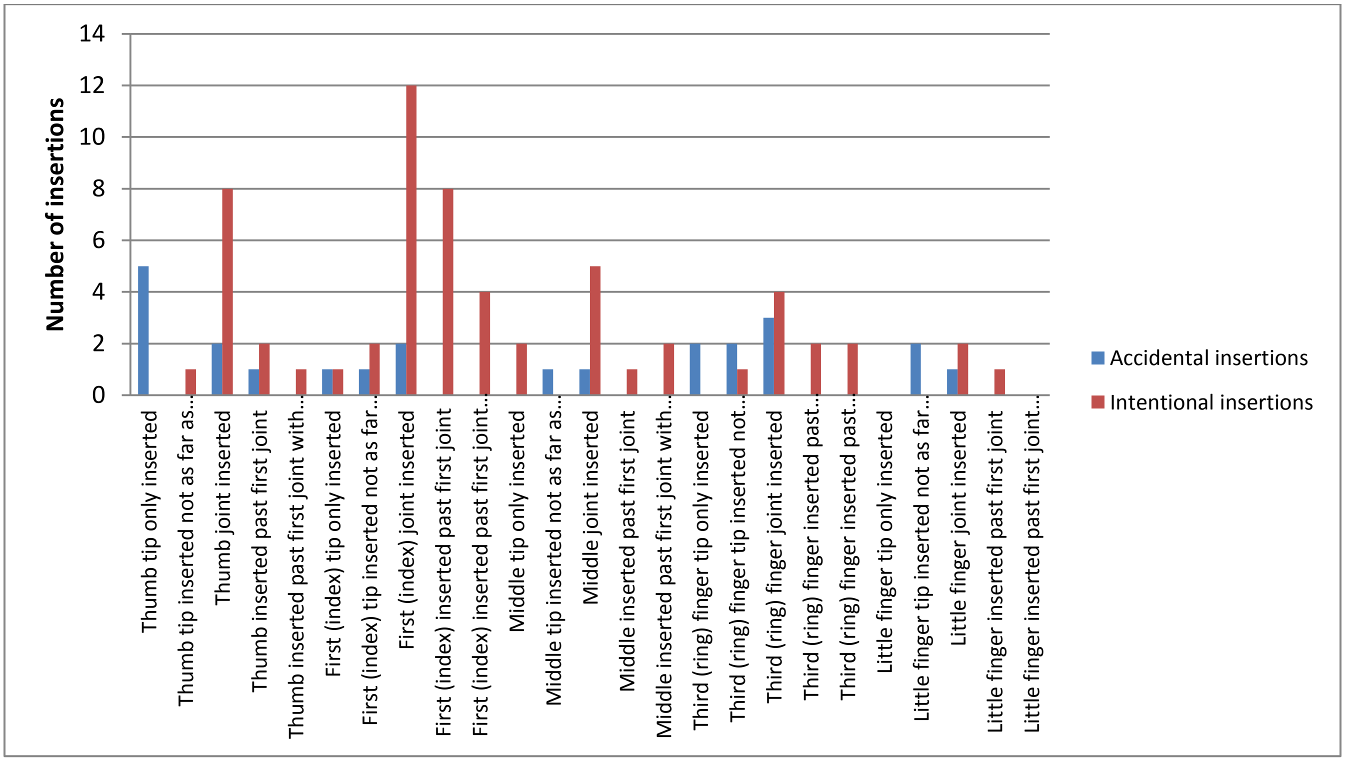


Figure 10 Accidental occurrences of insertion for all toys

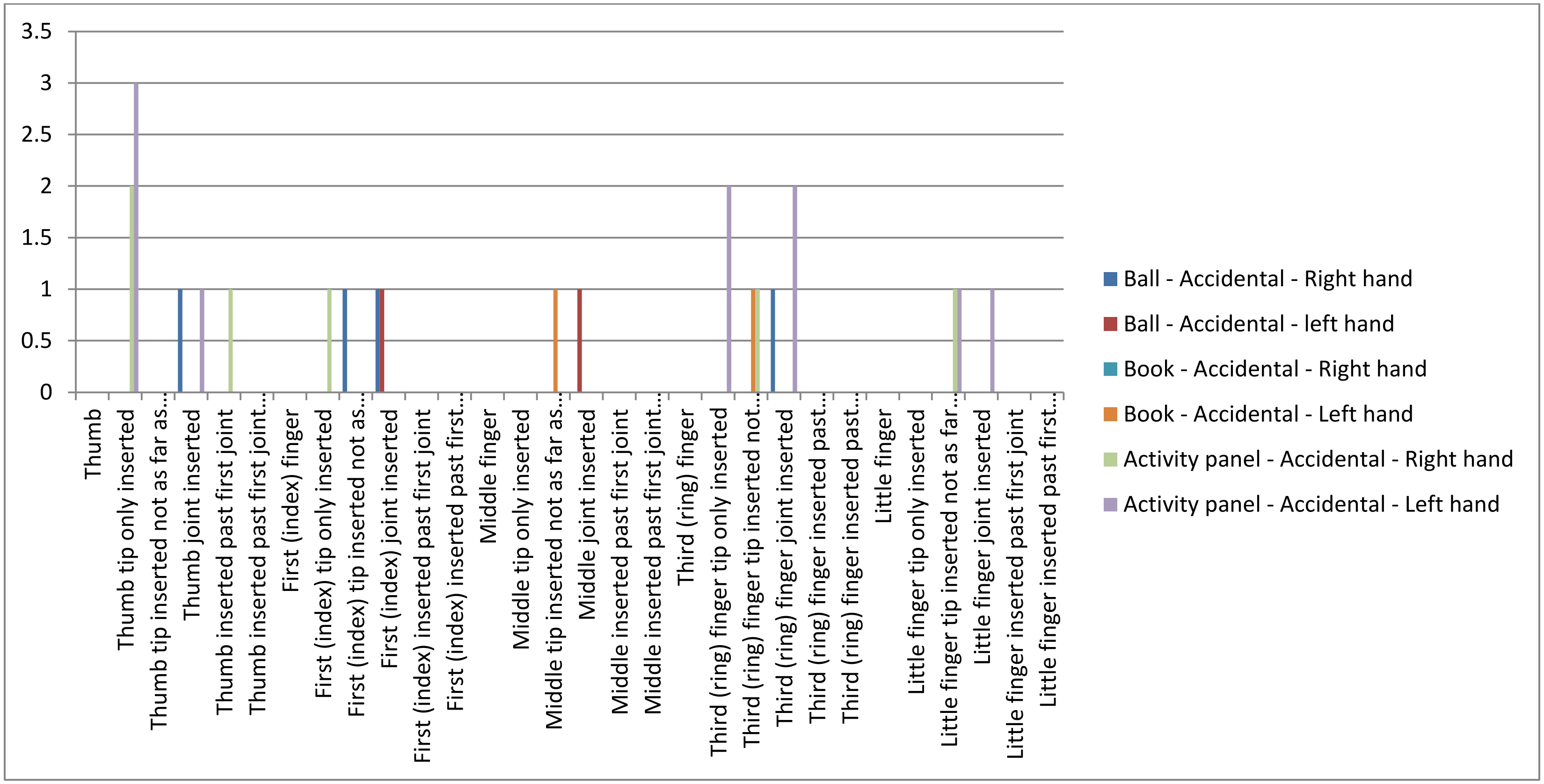
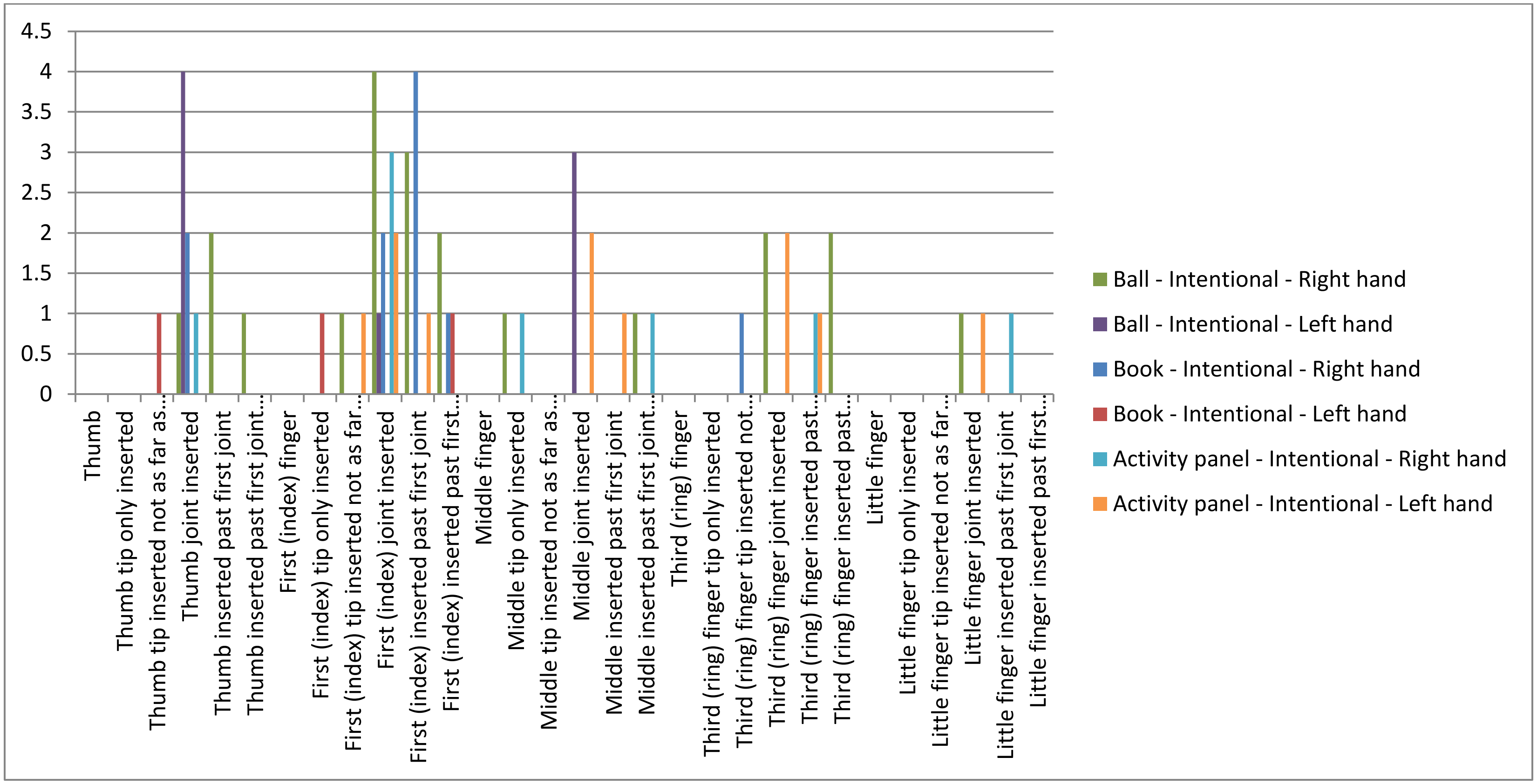


Figure 11 Intentional occurrences of insertion for all toys



6 Discussion and conclusions

An observation study of 28 children aged 5 to 18 months showed that children aged 6 months can accidentally insert their fingers into openings in toys as they explore. Also, children as young as 7 months were observed intentionally inserting their fingers into openings. Intentional insertions resulted in a 'deeper' insertion with the child more likely to insert the finger up to and past the distal joint. The index finger was most commonly (intentionally) inserted finger although all fingers were inserted, including the thumb and little finger. This study shows that requirements to protect children from finger entrapment should therefore be based on the finger sizes of children from 6 months.

A literature review in this study found that the majority of available anthropometric data on children's fingers was measured between the 1970s and 1990s. There has been an increase in children's body sizes since this time, but there are no data to specify exactly how this may affect the finger sizes of children as young as 6 months, the age at which finger entrapment becomes a risk. One recent study was found (measured on UK children in 1999) and from this data and other literature it is probably right to assume that there will have been an increase in finger size from the older published data, but this may be within the accuracy levels with which data are measured (e.g. 0.5-1mm intervals).

The published finger data were therefore reviewed, and some estimations were carried out to produce missing data, e.g. for the finger tip length of children under two years old.

The current dimensional requirements for static openings to protect children under 4 years of age were then reviewed in the light of the observation study and the published and estimated anthropometric data. The following recommendations are made:

	Minimum diameter requirement:	**Maximum diameter requirement:**	**Minimum depth requirement**
Current requirement:	5 mm	12 mm	10mm
Recommendations	No change for round or oval openings; reduce to 3 mm for slots, but as a guide only	Increase to 15.5 mm (to exclude entrapment of the thumb for four year olds) OR Increase to 14.5 mm (to exclude entrapment of the fingers only for four year olds)	10 mm is unlikely to protect children 2.5 years and younger. This should therefore be decreased to 3.5 mm to protect the smallest child in the youngest age group at risk (1st percentile infant aged 4-6 months) based on the tip length of the little finger, or 6 mm based on the finger tip of the middle finger

The work on dynamic entrapment hazards was a first review of possible future tests. The feasibility trial demonstrated that 3D modeling could be a useful technology to better inform how the finger may be affected by moving parts, in particular the effects on soft tissue. At present, the requirements are informed by static anthropometry of the joints of the fingers, which do not reflect how the fleshy parts of the fingers could be trapped, and the dimensional requirements to protect them. Broad recommendations have been made to reduce the requirements for moving parts in line with static requirements, but more work is required to specify these further.

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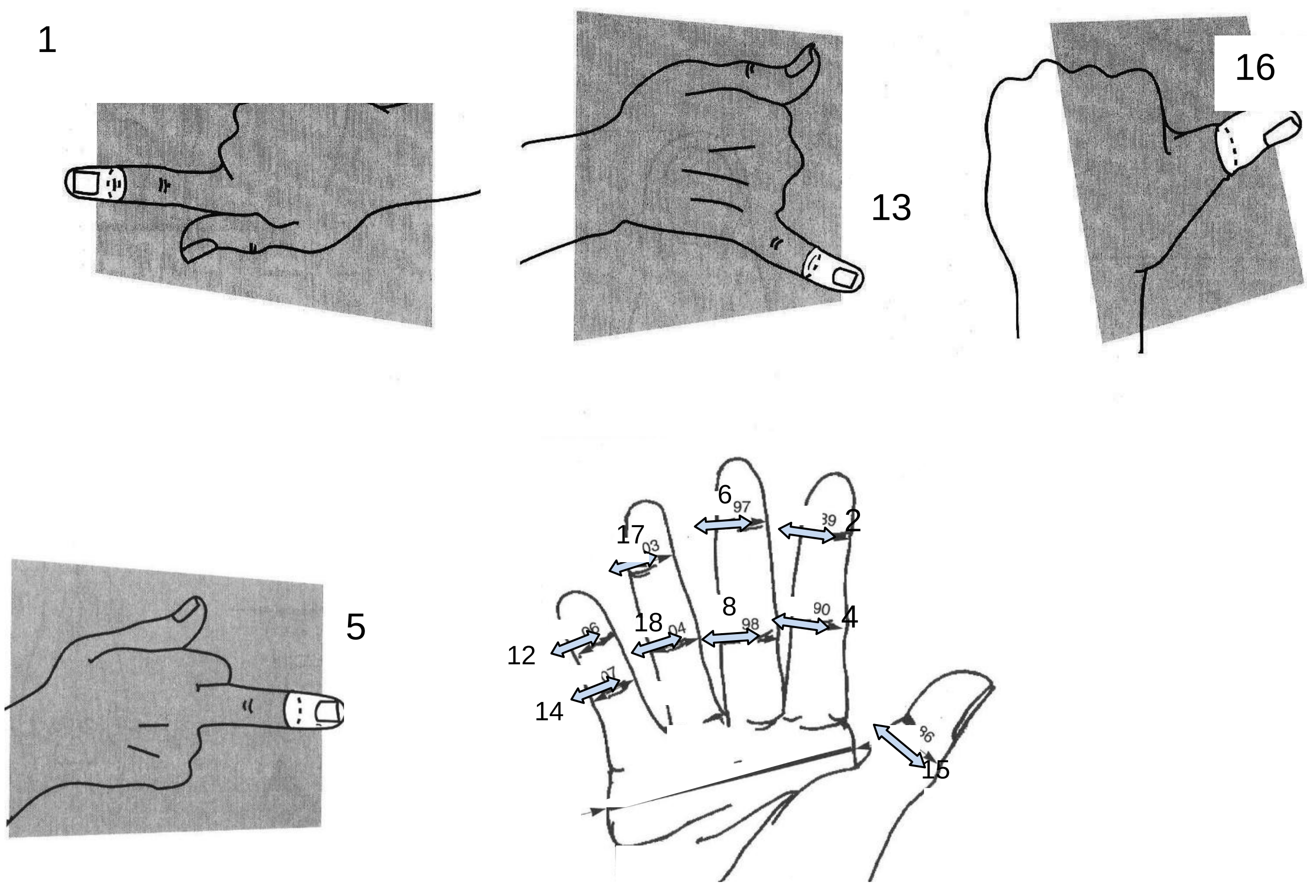
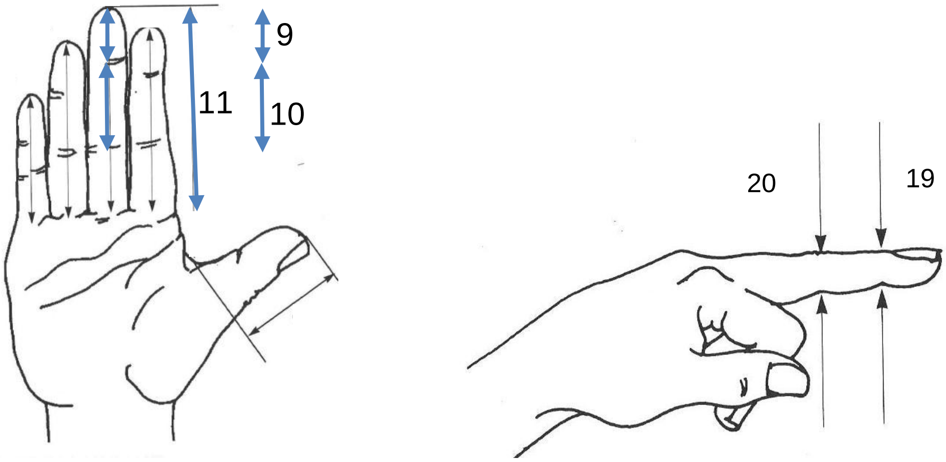
Appendix 1 – Anthropometric data tables

Illustrations of finger dimensions



Note: The diameter of the middle joint of the index and middle fingers is not illustrated



<u>INDEX FINGER</u>

Dimension 1. Distal joint DIAMETER* (mm)

UK males and females

AGE	Mean	SD	2.5%ile	97.5th%	1st%ile	99th%ile
6-8 mo	7.9	0.39	7	9	6.99	8.81
9 to 11	8.9	0.32	8	10	8.15	9.65
1-1.5 yrs	9.4	0.58	8	11	8.05	10.75
1.5-2	9.3	0.62	8	10	7.86	10.75
2-2.5	9.4	0.51	8	10	8.21	10.59
2.5-3	9.9	0.57	9	11	8.57	11.23
3-3.5	10.8	1.46	8	14	7.40	14.20
3.5-4	10.6	1.46	8	13	7.20	14.00
4-4.5	11.6	1.37	9	14	8.41	14.79

US males and females

AGE	Mean	SD	5th%	95th%	1st%ile	99th%ile
2.5-3.5yrs	9.6	0.6	8.4	10.2	8.20	10.99
3.5-4.5yrs	10.1	0.6	8.9	10.9	8.70	11.50

Dimension 2. Distal joint BREADTH (mm)

German males and females (data measured separately but values the same)

AGE	Mean	SD	5th% ile	95th%	1st%ile	99th%ile
3 years	11	0.61	10	12	9.59	12.41
4 years	12	0.61	11	13	10.59	13.41

Dimension 3. Middle joint DIAMETER* (mm)

UK males and females

AGE	Mean	SD	2.5%ile	97.5th% ile	1st%ile	99th%ile
6-8 mo	9.8	0.91	8	12	7.68	11.92
9 to 11	10.7	0.51	10	12	9.51	11.89
1-1.5 yrs	11.4	0.7	10	13	9.77	13.03
1.5-2	11.6	0.33	11	12	10.83	12.37
2-2.5	11.7	0.38	11	12	10.81	12.58
2.5-3	11.8	0.58	11	13	10.45	13.15

3-3.5	11.9	0.64	11	13	10.41	13.39
3.5-4	11.5	0.82	10	13	9.59	13.41
4-4.5	11.8	0.92	10	14	9.66	13.94

Dimension 4. Middle joint BREADTH (mm)

German males and females (data measured separately but values the same)

AGE	Mean	SD	5th% ile	95th% ile	1st%ile	99th%ile
3 yrs	13	1.21	11	14	10.18	15.82
4 yrs	14	1.21	12	15	11.18	16.82

MIDDLE FINGER

Dimension 5. Distal joint DIAMETER* (mm)

UK males and females

AGE	Mean	SD	2.5%ile	97.5th%	1st%ile	99th%ile
6-8 mo	8.3	0.42	7	9	7.32	9.28
9 to 11	9.2	0.55	8	10	7.92	10.48
1-1.5	9.2	0.55	8	10	7.92	10.48
1.5-2	9.7	0.48	9	10	8.58	10.82
2-2.5	9.6	0.4	9	10	8.67	10.53
2.5-3	10.3	0.71	9	12	8.65	11.95
3-3.5	11.1	1.48	8	14	7.65	14.55
3.5-4	10.9	1.09	9	13	8.36	13.44
4-4.5	11.9	1.3	9	14	8.87	14.93

US males and females

AGE	Mean	SD	5th% ile	95th% ile	1st%ile	99th%ile
0-2 mo	7.2	0.6	6.3	8.1	5.80	8.60

3-5mo	7.6	0.6	6.3	8.3	6.20	9.00
6-8mo	8.3	0.7	7.5	9	6.67	9.93
9-11mo	8.9	0.7	7.6	10	7.27	10.53
12to15	9	0.6	7.9	9.7	7.60	10.40
16to19	8.8	0.6	7.9	9.5	7.40	10.20
20to23	9.1	0.8	7.9	10.1	7.24	10.96
2-3.5 yrs	9.9	0.6	8.7	10.8	8.50	11.30
3.5-4.5 yrs	10.4	0.7	9.1	11.2	8.77	12.03

Dimension 6. Distal joint BREADTH (mm)

US males and females

AGE	Mean	SD	5th% ile	95th% ile	1st%ile	99th%ile
2.5-3.5 yrs	11	1	8	13	8.67	13.33
3.5-4.5 yrs	11	1	9	12	8.67	13.33

German males and females (data measured separately but same value)

AGE	Mean	SD	5th% ile	95th% ile	1st%ile	99th%ile
3 yrs	11	0.61	10.00	12.00	9.59	12.41
4 yrs	12	0.61	11.00	13.00	10.59	13.41

Dimension 7. Middle joint DIAMETER* (mm)

UK males and females

AGE	Mean	SD	2.5%ile	97.5th% ile	1st%ile	99th%ile
6-8 mo	10	1.01	8	12	7.65	12.35
9 to 11	10.8	0.5	10	12	9.64	11.97
1-1.5 yrs	11.5	0.71	10	13	9.85	13.15

1.5-2	11.7	0.28	11	12	11.05	12.35
2-2.5	11.7	0.31	11	12	10.98	12.42
2.5-3	12	0.48	11	13	10.88	13.12
3-3.5	12.1	0.4	11	13	11.17	13.03
3.5-4	11.8	0.96	10	14	9.56	14.04
4-4.5	12.1	1.02	10	14	9.72	14.48

Dimension 8. Middle Joint BREADTH (mm)

US males and females

AGE	Mean	SD	5th% ile	95th% ile	1st%ile	99th%ile
2.5-3.5 yrs	12	1	9	13	9.67	14.33
3.5-4.5 yrs	12	1	10	14	9.67	14.33

German males and females (data measured separately but same value)

AGE	Mean	SD	5th% ile	95th% ile	1st%ile	99th%ile
3 yrs	13	0.61	12.00	14.00	11.59	14.41
4 yrs	14	1.21	12.00	15.00	11.18	16.82

Dimension 9. MIDDLE FINGER length: tip to distal joint (mm)

US males and females

AGE	Mean	SD	5th% ile	95th% ile	1st%ile	99th%ile
2.5-3.5 yrs	13	2	9	15	8.34	17.66
3.5-4.5 yrs	14	2	10	16	9.34	18.66

Dimension 10. MIDDLE FINGER length: Middle joint to distal joint (mm)

US males and females

AGE	Mean	SD	5th% ile	95th% ile	1st%ile	99th%ile
2.5-3.5 yrs	16	6	12	20	2.02	29.98
3.5-4.5 yrs	17	2	13	20	12.34	21.66

Dimension 11. MIDDLE finger length (mm)

US males (except ages 3.5-4.5 and 4.5-5.5, males and females)

AGE	Mean	SD	5th% ile	95th% ile	1st%ile	99th%ile
0-3mo	30	4	23	39	20.68	39.32
4-6 mo	34	4	28	43	24.68	43.32
7-9 mo	37	5	27	46	25.35	48.65
10-12 mo	36	4	29	46	26.68	45.32
13-18 mo	39	3	33	45	32.01	45.99
19-24 mo	42	4	36	50	32.68	51.32
2-2.5	43	4	34	50	33.68	52.32
2.5-3	45	3	39	50	38.01	51.99
3-3.5	46	3	40	51	39.01	52.99
3.5-4.5	48	4	42	55	38.68	57.32
4.5-5.5	51	4	42	56	41.68	60.32

US females

AGE	Mean	SD	5th% ile	95th% ile	1st%ile	99th%ile
0-3mo	29	4	23	38	19.68	38.32
4-6 mo	32	4	23	41	22.68	41.32

7-9 mo	35	3	29	40	28.01	41.99
10-12 mo	36	3	31	42	29.01	42.99
13-18 mo	38	3	29	41	31.01	44.99
19-24 mo	42	4	36	49	32.68	51.32
2-2.5 yrs	43	3	37	48	36.01	49.99
2.5-3	45	4	38	51	35.68	54.32
3-3.5	46	3	40	51	39.01	52.99

Dutch males

AGE	Mean	SD	3rd% ile	97th% ile	1st%ile	99th%ile
2 yrs	45	3	39	50	38.01	51.99
3	49	4	43	55	39.68	58.32
4	51	3	45	56	44.01	57.99
5	54	4	47	60	44.68	63.32

Dutch females

AGE	Mean	SD	5th% ile	95th% ile	1st%ile	99th%ile
2 yrs	45	3	39	50	38.01	51.99
3	48	3	42	54	41.01	54.99
4	50	3	45	56	43.01	56.99
5	54	3	47	61	47.01	60.99

LITTLE FINGER

Dimension 12. Distal joint BREADTH (mm)

Dutch Males

AGE	Mean	SD	3rd%ile	97th%ile	1st%ile	99th%ile
0-2mo	7	1	6	8	4.67	9.33
3-5mo	7	1	6	10	4.67	9.33
6-8mo	8	1	6	9	5.67	10.33
9-11mo	8	0	7	8	8	8
12-14mo	8	0	7	9	8	8
2yrs	9	1	8	10	6.67	11.33
3yrs	10	1	8	11	7.67	12.33
4yrs	10	1	9	11	7.67	12.33

(15-17 month data not included because sample size too small)

Dutch females

AGE	Mean	sd	3rd%ile	97th%ile	1st%ile	99th%ile
0-2mo	6	1	5	7	3.67	8.33
3-5mo	7	1	5	8	4.67	9.33
6-8mo	7	1	6	9	4.67	9.33
9-11mo	7	1	6	9	4.67	9.33
12-14mo	8	1	6	9	5.67	10.33
15-18mo	**7**	**1**	**7**	**8**	4.67	9.33
2yrs	9	1	7	11	6.67	11.33
3yrs	9	1	8	11	6.67	11.33
4yrs	9	1	8	10	6.67	11.33

German males and females

AGE	Mean	SD	5th%ile	95th%ile	1st%ile	99th%ile
3yrs	10	0.61	9.00	11.00	8.59	11.41
4yrs	11	0.61	10.00	11.00	9.59	12.41

Dimension 13. Distal joint DIAMETER (mm)**

Dutch males

AGE	Mean	SD	3rd%ile	97th%ile	1st%ile	99th%ile
0-2mo	7	1	6	9	4.67	9.33
3-5mo	7	0	6	8	7	7
6-8mo	7	0	7	8	7	7
9-11mo	7	0	7	8	7	7
12-14mo	8	0	7	9	8	8

(15-17 month data not included because sample size too small)

Dutch females

AGE	Mean	SD	3rd%ile	97th%ile	1st%ile	99th%ile
0-2mo	6	0	6	7	6	6
3-5mo	6	1	5	7	3.67	8.33
6-8mo	7	0	6	7	7	7
9-11mo	8	1	7	8	5.67	10.33
12-14mo	8	0	7	8	8	8
15-18mo	7	0	7	8	7	7

Dimension 14. Middle joint BREADTH (mm)

German males and females (measured separtely but values the same)

AGE (yrs)	Mean	SD	3rd%ile	97th%ile	1st%ile	99th%ile
3yrs	10	0.61	9.00	11.00	8.59	11.41
4yrs	11	0.61	10.00	11.00	9.59	12.41

<u>THUMB</u>

Dimension 15. Distal Joint BREADTH (mm)
Dutch males

AGE	Mean	SD	3rd%ile	97th%	1st%ile	99th%ile
2 yrs	13	1	12	14	10.67	15.33
3	14	1	11	15	11.67	16.33
4	14	1	12	16	11.67	16.33
5 yrs	15	1	12	16	12.67	17.33

Dutch females

AGE	Mean	SD	3rd%ile	97th%	1st%ile	99th%ile
2 yrs	13	1	11	15	10.67	15.33
3	13	1	11	15	10.67	15.33
4	13	1	11	15	10.67	15.33
5 yrs	14	1	13	16	11.67	16.33

German males

AGE	Mean	SD	5th%ile	95th%ile	1st%ile	99th%ile
3 yrs	14	0.61	13.00	15.00	12.59	15.41
4	15	1.21	13.00	16.00	12.18	17.82
5	15	0.61	14.00	16.00	13.59	16.41

German females

AGE	Mean	SD	5th%ile	95th%ile	1st%ile	99th%ile
3 yrs	14	0.61	13.00	15.00	12.59	15.41
4	15	1.21	13.00	16.00	12.18	17.82
5	15	0.61	14.00	16.00	13.59	16.41

Dimension 16. Distal joint DIAMETER* (mm)

US males and females

AGE	Mean	SD	5th%ile	95th%ile	1st%ile	99th%ile
0 to 2 mo	8.6	0.8	7.1	9.7	6.736	10.464
3 to 5	9.2	0.8	7.4	10.2	7.336	11.064
6 to 8	9.9	0.7	8.7	10.7	8.269	11.531
9 to 11	10.6	0.8	9.5	11.8	8.736	12.464
12 to 15	11	0.7	8.8	11.7	9.369	12.631
16 to 19	10.7	0.7	9.5	11.7	9.069	12.331
20 to 23	11.4	1	9.6	12.6	9.07	13.73
2-3.5 yrs	12.4	0.9	10.5	13.5	10.303	14.497
3.5-4.5	13.1	0.9	11.1	14.1	11.003	15.197

THIRD (RING) FINGER

Dimension 17. Distal joint BREADTH (mm)

German males and females (measured separately but values the same)

AGE	Mean	SD	5th%ile	95th%ile	1st%ile	99th%ile
3 yrs	11	0.61	10.00	12.00	9.59	12.41
4	11	0.61	10.00	12.00	9.59	12.41

Dimension 18. Middle joint BREADTH (mm)

German males and females (measured separately but values the same)

AGE	Mean	SD	5th%ile	95th%ile	1st%ile	99th%ile
3 yrs	12	0.61	11.00	13.00	9.59	13.41
4	13	0.61	12.00	14.00	9.59	14.41

Dimension 19. Middle finger distal joint DEPTH (mm)

US males and females

AGE (yrs)	Mean	SD	5th%	95th%	1st%ile	99th%ile
2.5-3.5 yrs	9	1	8	11	6.67	11.33
3.5-4.5 yrs	10	1	8	11	7.67	12.33

Dimension 20. Middle finger middle joint DEPTH (mm)

US males and females

AGE (yrs)	mean	SD	5th%	95th%	1st%ile	99th%ile
2.5-3.5 yrs	11	1	8	13	8.67	13.33
3.5-4.5 yrs	11	1	9	13	8.67	13.33

* **Defined as the largest aperture size through which a finger will not pass EXCEPT ** which is the largest aperture size through which a finger WILL pass**

Appendix 2 - Observation recording sheet

Please complete a separate form for each child and for each toy.

1. **Child number:……………………………………………………………………………..**

2. **Toy number: :……………………………………………………………………………..**

3. **Time of day the observation was carried out:……………………………………………...**

4. **Length of time child plays with toy: From:………………… to:……………………**

5. **Where did you observe the child (e.g. name of nursery and room)…………………**

6. **What does the child do with the toy (circle one only)?**

   a. S(he) plays with toy, does not touch opening.

   b. S(he) plays with toy and touches an opening but does not insert finger.

   c. S(he) plays with toy and touches several openings but does not insert finger.

   d. S(he) touches several openings and inserts finger into one opening

      - If s(he) does this more than once, how many times?..........

   e. S(he) touches several openings and inserts finger into more than one opening

      - If s(he) does this more than once, how many times?..........

7. **If s(he) puts a finger into the opening, how far does it go?**

How many times (circle one)?

a.	Finger tip only inserted	1	2	3	4	5+
b.	Finger tip inserted, not as far as first knuckle	1	2	3	4	5+
c.	First finger joint inserted	1	2	3	4	5+
d.	Finger inserted past first joint	1	2	3	4	5+
e.	Finger inserted past first joint with force	1	2	3	4	5+

8. If s(he) puts a finger into the opening, which finger is it?

Left hand	**Right hand**
☐ Thumb	☐ Thumb
☐ 1st (index) finger	☐ 1st (index) finger
☐ Middle finger	☐ Middle finger
☐ 3rd (ring) finger	☐ 3rd (ring) finger
☐ Little finger	☐ Little finger

Observation recording sheet

Action Observed	**Child details/notes**	**Child details/notes**	**Child details/notes**
Child plays with toy, does not touch opening.			
Child plays with toy and touches an opening but does not insert finger.			
Child plays with toy and touches several openings but does not insert finger.			
Child touches several openings and inserts finger into one opening			
Child touches several openings and inserts finger into more than one opening			
Child inserts finger and manoeuvres finger in opening			