Consumer and Competition Policy Directorate

Specific anthropometric and strength data for people with dexterity disability.

dti
Department of Trade and Industry

August 2002

Research commissioned by the Consumer and Competition Policy Directorate, DTI.

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Executive Summary

To enable people to interface with consumer products and ordinary house fittings, they must be designed in such a way that they are easy and convenient and safe to use. In order that this can happen, the physical, perceptual and psychological demands that the designs of products make when 'used', must be well within the capacities of the people who use them. If this requirement is not met, the product can be difficult or impossible to use or may give rise to misuse. A consequence of this may be injury to the user or to others who are nearby or those who subsequently use the product. An essential ergonomics requirement therefore, to assist designers of consumer goods, is to know what the capabilities of people are in respect of the use of consumer goods.

The DTI Consumer and Competition Policy Directorate, have, for many years been concerned with promoting the safety of consumer products in order to reduce injuries arising from accidents. To assist designers to make products safer, the DTI has commissioned the development of human factors data with regard to children, adults and older people. The data produced from such measurements should assist designers to develop everyday consumer products that can be used safely and efficiently by as wide a range as possible.

A previous study of the difficulties that disabled people have when using everyday consumer products, DTI 2000, was concerned with identifying the actual problems disabled people face when using consumer products. The products included those that might be considered essential for everyday use such as those involved in food preparation, laundering and cleaning the house. Besides identifying the products disabled people had most difficulty with, the study also identified the strategies disabled people needed to use when coping with consumer products. These strategies generally involved motor factors such as reaching, gripping and manipulation, but also included lifting and transporting. Process factors such as the organising and sequencing of the component activities were not so much involved due to the fact that the sample included very few people with significant learning disabilities.

The report also identified the types of measurements that would need to be made in order to provide designers with the data they require when determining the limits of force that should be employed when using consumer products. A subsequent pilot study examined the feasibility of carrying out a large-scale survey to measure the force capabilities of disabled people with respect to their use of consumer products. This demonstrated that it was feasible to carry out such a study and that the number of disabled people studied should be several hundred.

This DTI 2000 study describes such a study and provides data on the strength capabilities of disabled people over a number of hand functions. The study also attempted to estimate the proportions of people capable of exerting different levels of strength in relation to these hand functions.

Over 300 disabled persons were included in the study. These were carefully selected to accurately represent disabled people generally who had reaching, dexterity and manipulation impairments. The basis for selecting the sample was the Office of Population Censuses and Surveys (Martin et al 1988) study that reported on the prevalence of disability among adults in England and Wales.

In addition, a control group of 95 non-disabled adults were selected in order to compare the results with those from the disabled group.

Based on these findings, a series of six hand strength measurements were identified, as the most important data need:

- **Two handed grip and twisting strength**
- **One handed lifting strength (horizontal handle)**
- **One handed lifting strength (vertical handle)**
- **Finger grasp and pull strength**
- **Ring pull strength**

In addition, certain body dimensions that were considered relevant to the design and use of consumer products were identified as being of importance. These included:

- **Finger/thumb dimensions**
- **Hand span**
- **Thumb/finger grasping diameter**
- **Elbow height**

The results demonstrate considerable differences between the strength capabilities of disabled people and non-disabled people. In all of the tests the strength capabilities of non-disabled people was between two and three times that of disabled people. This poses a considerable challenge to designers and manufacturers of consumer products if they are to produce products that disabled people will be able to use with the same degree of ease and convenience and with a similar level of safety as that expected by non-disabled people.

While the results showed little significant difference between the hand / finger sizes of disabled people as compared with non-disabled people, the functional anthropometric characteristics were significantly different. For example the hand span of disabled people i.e. the maximum grip capability between the thumb and any finger, was significantly less than that of non-disabled people. This was also true for the maximum grip diameter – i.e. the maximum diameter that can be grasped with the thumb and middle finger when just in contact.

The previous DTI 2000 study described the difficulties disabled people have with consumer products and demonstrated that very large numbers of disabled people are involved. This report confirms that large numbers of disabled people do indeed have very low strength capabilities and if their demands are to be met, radically different solutions in consumer products interface design are required.

The experience with this project demonstrated the feasibility of collecting representative data on the strength capabilities and hand anthropometric characteristics of people with disabling conditions resulting in restricted reach and dexterity. The data collected is reliable and validated and as such if applied appropriately to the design of consumer products will make them easier and safer to use by disabled people.

Overview

The previous DTI 2000 study results showed large numbers of disabled people had difficulty in using everyday consumer products. The study showed for example, that over million people had real difficulties in opening jam jars. As a result of that study the DTI commissioned study to develop data on the different strength capabilities of disabled people. The idea being that if designers could design products that, if when used, are within disabled people's capabilities, then they could use them easily and effectively and more safely. Moreover if such products met disabled people's requirements in terms of the strength needed to use the product, they would also meet the requirements of non-disabled people. This would allow manufacturers to develop a strong business case for more inclusive design.

The results of this research gives strength data for a whole range of different lifting capabilities of disabled people. Again using the jam jar as an example, the data gives the limits to the amount of force needed to unscrew a jam jar lid for different percentages of the disabled population. If designers want to ensure that 90% of the disabled population are catered for then the maximum force or more specifically, the torque for a 65 mm diameter lid with a smooth surface should be limited to .25 Newton-metres.

Such data can be used by manufacturers and designers to develop business cases for more inclusive design. For example the data can be used to demonstrate the increase in the number of people able to use the product easily and effectively if the torque was kept below a certain level. The results of the research thus provide evidence upon which manufacturers can define the potential markets for their products based on strength required for opening.

The report provides data on the strength capacities of disabled and non-disabled people for gripping and twisting strength, lifting strength (as with lifting a kettle or saucepan), finger grasping and pulling strength and ring-pull strength. In addition data is provided on people's fingers and hand dimensions and maximum grasping dimensions.

Over 400 persons were included in the study. They included nearly 100 non-disabled adults and over 300 disabled people. They were carefully selected to accurately represent disabled and non-disabled people generally in terms of their reaching, dexterity and manipulation capabilities.

Chapter 1
Introduction

The previous DTI 2000 study was concerned with identifying the actual problems disabled people face when using consumer products. The products included those that might be considered essential for everyday use such as those involved in food preparation, laundering and cleaning the house. Besides identifying the products disabled people had most difficulty with, the study also identified the strategies disabled people needed to use when coping with consumer products. These strategies generally involved motor factors such as reaching, gripping and manipulation, but also included lifting and transporting. Process factors such as the organising and sequencing of the component activities were not so much involved due to the fact that the sample included very few people with significant learning disabilities.

The interview and assessment study highlighted a number of products that caused difficulty for disabled people. These included packaging, household utensils, machine controls and large and heavy items such as vacuum cleaners. A further, simple questionnaire survey showed that most disabled people cannot use many of the commonly available DIY and garden implements.

For the purposes of measuring disabled people's capabilities it is necessary to examine in greater detail the specific component and the strategies that were employed. Many of these apply to all people, disabled or otherwise. They include hand manipulation activities such as grasping (either with fingers or palm), twisting, pinching, pulling and tearing. It is with respect to these specific activities that the capabilities of disabled people need to be measured in order that designers can design products whose use demands are well within those capabilities.

The basis for selecting the hand function tests to be included in this study was two-fold. Firstly, the previous research demonstrated the types of products that disabled people had and the type of hand function capabilities that were involved with such products. This served as the basis for determining which hand function tests should be made in relation to the problems disabled people have. In addition, the results of a study by the University of Nottingham on the capabilities of children, adults and older people described a number of hand function tests that would be generally involved in the use of consumer products.

Based on these findings, a series of six hand strength measurements were identified, as the most important data need:

- **Two handed grip and twisting strength**
- **One handed lifting strength (horizontal handle)**
- **One handed lifting strength (vertical handle)**
- **Finger grasp and pull strength**
- **Ring pull strength**

In addition, certain body dimensions that were considered relevant to the design and use of consumer products were identified as being of importance. These included:

- **Finger/thumb dimensions**
- **Hand span**
- **Thumb/finger grasping diameter**
- **Elbow height**

The general approach used to obtain the measurements including sampling is described in Appendix 1. The analysis of the results of each of the measurements are described in different sections with the analysis of the results from the disabled and non-disabled groups. In most instances the results for the disabled group have been analysed according to the different severity levels for dexterity impairments described in the OPCS survey (see Appendix 1).

Chapter 2
Two handed grip and twisting strength (as when unscrewing a jar lid)

2.1 DESCRIPTION

The maximum static anti-clockwise torque that can be applied to the lid of an instrumented replica jar with smooth and knurled textured lids of various diameters.

2.2 METHOD

The participant stood[1] (ambulant persons) or sat (wheelchair users) adopting an otherwise free posture. The participant grasped an instrumented replica jar with both hands in the preferred manner - as when unscrewing the lid of a jar. With the 'lid' in the one hand and the body in the other the participant was asked to apply maximum twisting strength (or torque) in an anti-clockwise manner and hold this for two or three seconds. The maximum force, which was automatically shown in a visual display, was recorded. The action was repeated twice more and recordings made.

2.3 EQUIPMENT

Three specially made instrumented aluminium jars of 125 mm height with diameters of 45, 65 and 85 mm with attachable brass knurled or smooth 'lids'.

[1] In a few cases ambulant participants preferred to sit.

2.4 ANALYSIS

2.4.1. Effect of disability

The mean values for the non-disabled group were 2 to 2 1/2 greater than those for the disabled group for both 'smooth' and 'knurled' lids (see Tables 2.5.1 and 2.5.2).

The non-disabled group performed significantly better than the disabled group at the $p<01$ level[2].

2.4.2. Effect of impairment severity

The maximum twisting strength (torque) that could be applied with each of the three diameters of 'jars', whether with knurled or smooth 'lids', was inversely related to severity of impairment (see Table 2.5.1). Significant differences were found between most of the severity categories with the main exceptions being those at either end of the scale (see Table 1, Appendix 2). It should be noted that in one or two cases mean values deviate from this trend. Such anomalies occur where the numbers of participants in a particular severity category is small. In such cases one or two participants can have an undue influence on the mean values.

2.4.3. Effect of 'lid' diameter and texture

Maximum twisting strength was found to increase with increase in lid size for both disabled and non-disabled groups. The effect of knurling the 'lids' produced higher torque for all 3 diameters (see Table 2.5.1). Both of these results were found to be significant at the $p<0.01$ level. Correlation coefficients are also shown in Table 2, Appendix 2.

2.4.4. Estimations of incidence of different levels of twisting strength for people with dexterity impairments

Based on the results from this sample, estimates were made using the OPCS results, of the total numbers of people with dexterity impairments with different strength capabilities (see Table 2.5.3). It should be noted that the total numbers level out at force levels below 4 Nm and proportions forces less than 4 Nm are therefore not given.

2.4.5. Proportions of persons with dexterity impairment accommodated with different two handed twisting strength levels for 3 different diameters.

From the results the proportion of persons with dexterity impairment who are accommodated at different two hand twisting torque levels have been calculated for three diameters for both smooth and knurled 'lids' (see Chart 2.5.4).

[2]For description of statistical definitions see Appendix 2, p49.

2.5 RESULTS

2.5.1. Two handed twisting strength (torque) applied by disabled participants for three different diameter 'lids' with 'smooth' and 'knurled' surfaces according to severity of dexterity[3] impairment

OPCS Dexterity		45mm Lid (Nm)					65mm Lid (Nm)					85mm Lid (Nm)				
	Lid texture	No.	Mean	S.D.	Min	Max	No.	Mean	S.D.	Min	Max	No.	Mean	S.D.	Min	Max
10.50	Smooth	14	0.82	0.79	0.07	2.64	15	1.37	1.82	0.21	7.06	12	1.36	1.33	0.26	4.28
	Knurled	14	0.98	0.78	0.17	2.80	15	1.45	1.69	0.21	6.68	12	1.46	1.41	0.29	4.51
9.50	Smooth	18	0.51	0.50	0.08	1.92	19	0.72	0.63	0.08	1.96	17	0.84	0.64	0.10	2.25
	Knurled	18	0.47	0.42	0.09	1.29	20	0.73	0.71	0.04	2.69	18	0.88	0.76	0.10	2.67
8.00	Smooth	25	0.68	0.48	0.08	2.30	27	1.07	0.87	0.03	4.53	26	1.00	0.78	0.19	4.05
	Knurled	25	0.76	0.56	0.23	2.89	27	1.16	0.82	0.34	4.14	26	1.27	0.89	0.30	4.65
7.00	Smooth	32	1.08	1.07	0.14	6.20	34	1.30	0.76	0.21	3.79	33	1.71	1.61	0.18	8.08
	Knurled	32	1.32	1.19	0.21	6.48	34	1.62	1.46	0.14	8.64	34	1.80	1.78	0.20	10.25
6.50	Smooth	52	1.40	1.57	0.09	10.13	54	1.60	1.14	0.09	5.55	53	1.68	1.09	0.10	4.82
	Knurled	52	1.38	0.96	0.12	3.98	54	1.74	1.15	0.21	4.24	53	1.97	1.34	0.33	5.28
5.50	Smooth	36	1.06	0.72	0.15	2.47	37	1.50	1.16	0.27	6.76	35	1.64	0.91	0.46	4.32
	Knurled	36	1.37	1.02	0.24	5.20	37	1.58	0.94	0.31	3.95	35	1.72	0.80	0.61	3.59
4.00	Smooth	23	1.73	1.40	0.22	6.22	24	1.79	1.18	0.34	4.52	23	2.16	1.69	0.29	6.67
	Knurled	23	1.51	1.16	0.34	5.21	24	2.15	1.50	0.42	5.77	24	2.40	1.71	0.44	7.35
3.00	Smooth	16	1.34	0.78	0.17	2.79	19	1.96	1.28	0.12	4.72	19	2.13	1.19	0.39	4.23
	Knurled	17	1.49	0.90	0.16	2.79	20	2.11	1.29	0.21	4.32	19	2.31	1.31	0.46	4.60
2.00	Smooth	19	1.20	1.17	0.16	5.43	22	1.45	1.16	0.16	4.97	22	1.78	1.80	0.20	8.03
	Knurled	19	1.30	1.14	0.38	5.11	22	1.50	1.36	0.28	5.60	21	1.93	1.61	0.30	6.61
1.50	Smooth	5	1.40	0.84	0.41	2.57	5	3.33	0.92	0.92	8.66	5	2.32	1.11	0.65	3.49
	Knurled	5	1.68	1.10	0.34	3.13	5	2.32	1.05	0.81	3.26	5	2.49	1.08	0.66	3.45
0.50	Smooth	9	1.44	0.97	0.37	3.02	9	1.93	1.28	0.70	4.73	9	1.90	1.03	1.17	4.47
	Knurled	9	1.84	1.09	0.47	3.95	9	1.93	1.08	0.79	3.96	9	2.07	1.12	1.29	4.89
All categories	Smooth	249	1.15	1.12	0.07	10.13	265	1.49	1.22	0.03	8.66	254	1.64	1.29	0.10	8.08
	Knurled	250	1.26	1.01	0.09	6.48	267	1.61	1.25	0.04	8.64	256	1.82	1.37	0.10	10.25

[3]See Appendix 1 p45 for explanation of dexterity.

2.5.2. Two-handed twisting strength torque applied by non-disabled participants for three different diameter 'lids' with 'smooth' and 'knurled' surfaces

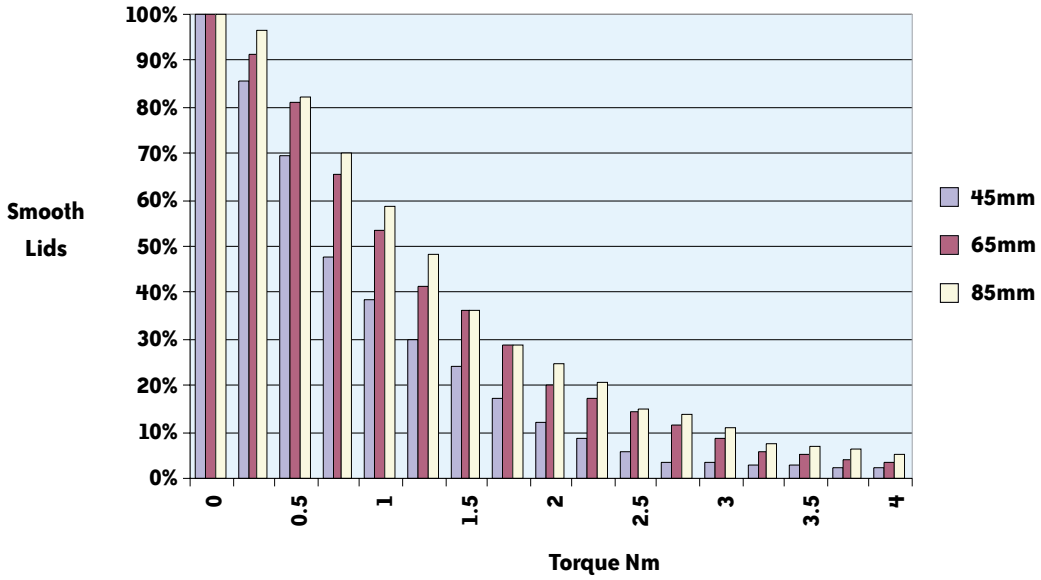
	45mm Lid (Nm)					65mm Lid (Nm)					85mm Lid (Nm)				
Lid texture	**No.**	**Mean**	**S.D.**	**Min**	**Max**	**No.**	**Mean**	**S.D.**	**Min**	**Max**	**No.**	**Mean**	**S.D.**	**Min**	**Max**
Smooth	124	2.58	1.28	0.22	6.56	125	3.47	1.74	0.52	8.78	125	4.05	2.08	0.63	11.30
Knurled	124	2.86	1.41	0.33	8.19	125	3.72	1.68	0.34	9.04	124	4.26	2.06	0.41	11.19

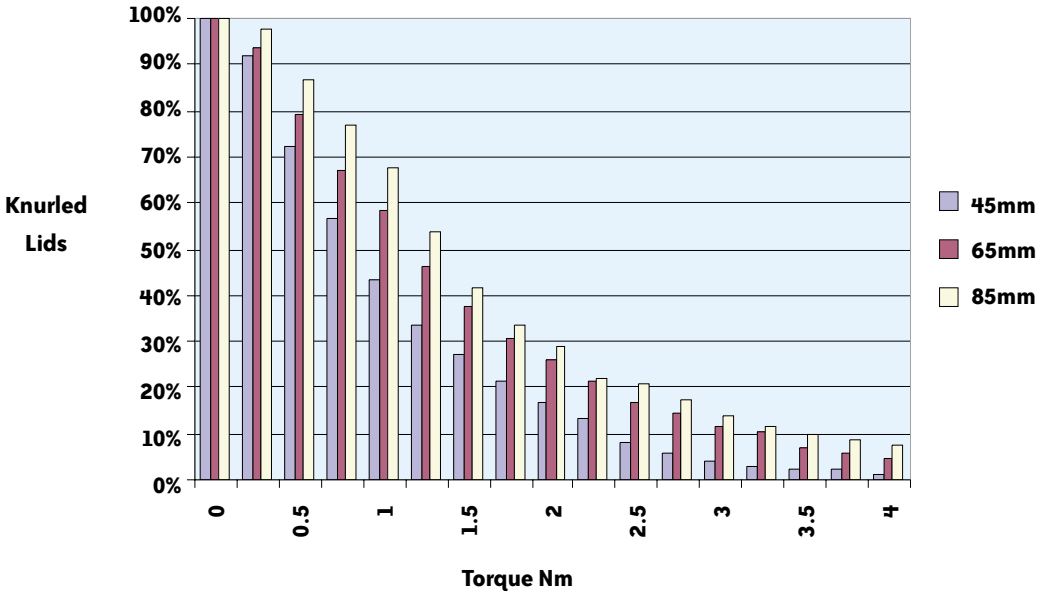
2.5.3. Estimated numbers (1000s) of people with dexterity impairment in Great Britain according to torque level that can be applied for three different diameter 'lids' and with 'smooth' and 'knurled' surfaces

Smooth lid																	
Force Nm	**0**	**0.25**	**0.5**	**0.75**	**1**	**1.25**	**1.5**	**1.75**	**2**	**2.25**	**2.5**	**2.75**	**3**	**3.25**	**3.5**	**3.75**	**4**
45 mm	1672	1523	1357	1101	896	691	611	486	334	290	245	193	141	96	83	65	58
65 mm	1672	1523	1357	1101	896	691	611	486	334	290	245	193	141	96	83	65	58
85 mm	1672	1621	1379	1173	982	810	604	483	413	347	248	232	180	128	118	105	82

Knurled lid																	
Force Nm	**0**	**0.25**	**0.5**	**0.75**	**1**	**1.25**	**1.5**	**1.75**	**2**	**2.25**	**2.5**	**2.75**	**3**	**3.25**	**3.5**	**3.75**	**4**
45 mm	1672	1532	1206	944	729	557	451	353	277	219	138	97	70	51	40	40	18
65 mm	1672	1570	1320	1117	973	774	624	513	436	358	280	242	193	173	117	97	74
85 mm	1672	1636	1446	1286	1127	902	694	558	483	370	342	289	231	193	162	145	126

2.5.4. Proportion of people with dexterity impairments capable of exerting different levels of two hand twisting force (torque) when grasping different diameter 'lids' with smooth and knurled texture





Chapter 3
One handed lifting strength

3.1 DESCRIPTION

The maximum static weight that can be lifted off a table top with one hand when grasping a horizontal or a vertical handle attached to a wooden platter on which different weights can be placed.

3.2 METHOD

The participant stood[4] (ambulant persons) or sat (wheelchair users) adopting an otherwise free posture. Grasping the handle of the platter the participant was to attempt to lift the lowest weight placed on the platter. The test was repeated with an increasing number of 0.25 Kg weights and a recording made of the maximum weight lifted. For each weight lifted, participants were asked to rate the task in terms of the level of ease or difficulty.

3.3 EQUIPMENT

Two specially made wooden platters were used each consisting a platform with a peg on which up to five 0.25 Kg weights could be placed. Attached to one platter was a horizontal handle of 30 mm diameter. Attached to the other was a vertical handle of 30 mm diameter.

[4]In a few cases ambulant participants preferred to sit.

3.4 ANALYSIS

3.4.1 Effect of disability

Tables 3.5.1 and 3.5.2 show the numbers of percentages of the disabled and non-disabled participants according to the level of ease of difficulty experienced when lifting different weights. Chart 3.5.3 shows the numbers involved in chart form.

It is clear that the proportion of non-disabled participants able to lift different weights were much greater than those for disabled participants. This was particularly true at the higher weights.

3.4.2 Effect of impairment severity

Severity of impairment was inversely related to the amount that could be lifted for both the horizontal and vertical handles (see Table 3.5.4). Although this trend is clear for all weights with both horizontal and vertical handles some significant deviations from the general trend line occurs. This may be explained by the fact that the task had a reaching element as well as dexterity and may have influenced whether participants were able to lift the loaded platter. A further factor was that a small number of those in the more severe categories used two hands to lift the weights, as this was the only way they could complete the task. Finally, the results only refer to those who completed the task and subjectively did so without due difficulty. This may have introduced an element of unreliability, particularly when bearing in mind that people with disabilities experienced more pain when carrying out such activities and this may well influence subjective ratings.

3.4.3 Effect of handle orientation

Disabled participants performed better with the vertical handle with the 0.25 Kg weight. At higher levels, little difference was found. With non-disabled participants little difference in performance between the vertical and horizontal handles was evident.

3.4.4 Estimation of the numbers of people with dexterity impairments who can lift different weights

Based on the results from this sample, estimates can be made using the OPCS results of the total number of people with dexterity impairments with different lifting capabilities (see Table 3.5.5).

3.4.5 Proportions of persons with dexterity impairments capable of lifting different weights

By adding together those who could lift different weights i.e. those in the categories 'Can do', 'Easy' and 'Very easy', it is possible to calculate the proportion who managed the task comfortably for each severity category (see Chart 3.5.6).

3.5 RESULTS

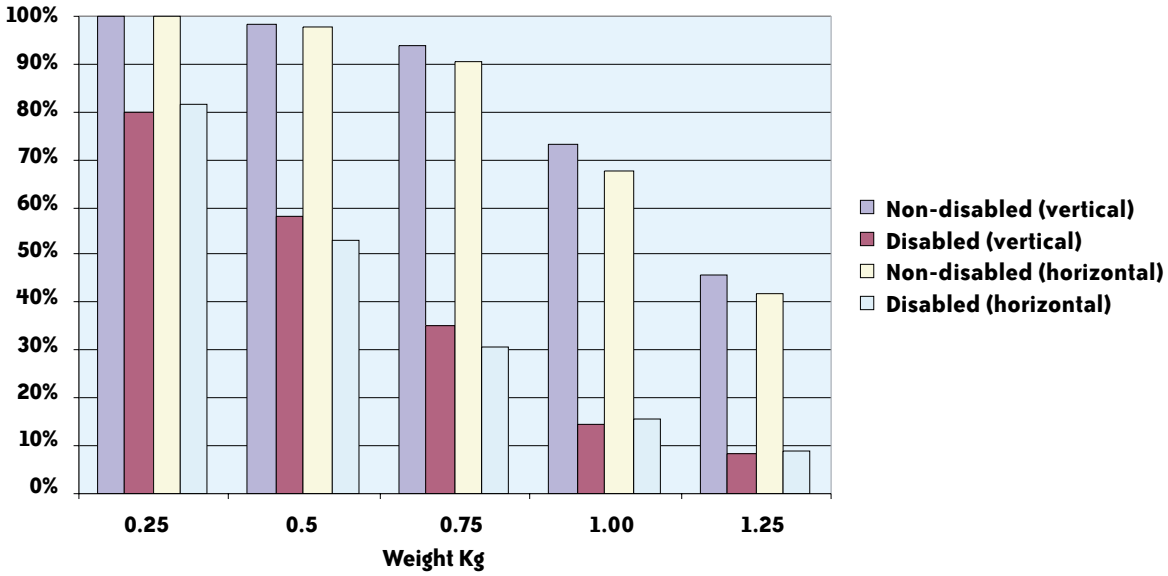
3.5.1 Numbers (and percentages) of disabled participants according to the level of ease or difficulty experienced when lifting different weights on a platter equipped with a horizontal or a vertical handle

Weights - horizontal handle					
	0.25Kg	**0.5Kg**	**0.75Kg**	**1Kg**	**1.25Kg**
Cannot do	30 (10%)	88 (29%)	155 (52%)	205 (69%)	233 (78%)
Very difficult	26 (9%)	53 (18%)	51 (17%)	47 (16%)	38 (13%)
Can do	62 (21%)	72 (24%)	57 (19%)	25 (8%)	14 (5%)
Easy	100 (33%)	63 (21%)	27 (9%)	20 (7%)	10 (3%)
Very easy	82 (27%)	24 (8%)	9 (3%)	2 (1%)	2 (1%)
Weights - vertical handle					
	0.25Kg	**0.5Kg**	**0.75Kg**	**1Kg**	**1.25Kg**
Cannot do	35 (12%)	82 (28%)	136 (51%)	184 (63%)	219 (76%)
Very difficult	25 (8%)	39 (13%)	25 (9%)	55 (19%)	45 (16%)
Can do	42 (14%)	67 (23%)	58 (22%)	30 (10%)	8 (3%)
Easy	100 (33%)	71 (24%)	34 (13%)	19 (6%)	14 (5%)
Very easy	97 (32%)	36 (12%)	13 (5%)	5 (2%)	3 (1%)

3.5.2 Numbers (and percentages) of non-disabled participants according to the level of ease or difficulty experienced when lifting different weights on a platter equipped with a horizontal or a vertical handle

Weights - horizontal handle					
	0.25Kg	**0.5Kg**	**0.75Kg**	**1Kg**	**1.25Kg**
Cannot do	0 (0%)	0 (0%)	2 (2%)	10 (8%)	24 (19%)
Very difficult	0 (0%)	3 (2%)	10 (8%)	31 (25%)	49 (39%)
Can do	3 (2%)	16 (13%)	41 (33%)	50 (40%)	29 (23%)
Easy	25 (20%)	59 (47%)	55 (44%)	28 (22%)	21 (17%)
Very easy	98 (78%)	48 (38%)	18 (14%)	7 (6%)	3 (2%)
Weights - vertical handle					
	0.25Kg	**0.5Kg**	**0.75Kg**	**1Kg**	**1.25Kg**
Cannot do	0 (0%)	0 (0%)	1 (1%)	7 (6%)	21 (17%)
Very difficult	0 (0%)	2 (2%)	7 (6%)	27 (21%)	47 (37%)
Can do	3 (2%)	8 (6%)	43 (34%)	47 (37%)	30 (24%)
Easy	13 (10%)	44 (35%)	43 (34%)	32 (25%)	22 (17%)
Very easy	110 (87%)	72 (57%)	32 (25%)	13 (10%)	6 (5%)

3.5.3 Proportion of disabled and non-disabled participants able to comfortably lift different weights on a platter equipped with a horizontal or vertical handle



3.5.4 Numbers and percentages of disabled participants with different dexterity impairment levels who could lift different weights without undue difficulty when using a horizontal or vertical handle

Horizontal handle						
Dexterity category	**No.**	**0.25Kg**	**0.5Kg**	**0.75Kg**	**1Kg**	**1.25Kg**
10.5	19	12 (63%)	7 (37%)	5 (26%)	4 (21%)	2 (11%)
9.5	23	12 (52%)	6 (26%)	4 (17%)	3 (13%)	3 (13%)
8	30	20 (67%)	8 (27%)	5 (17%)	3 (10%)	3 (10%)
7	34	28 (82%)	18 (53%)	9 (26%)	3 (9%)	2 (6%)
6.5	62	49 (79%)	30 (48%)	14 (23%)	6 (10%)	3 (5%)
5.5	42	38 (90%)	27 (64%)	16 (38%)	7 (17%)	4 (10%)
4	26	24 (92%)	13 (50%)	8 (31%)	5 (19%)	3 (12%)
3	20	19 (95%)	17 (85%)	8 (40%)	5 (25%)	5 (25%)
2	25	22 (88%)	19 (76%)	17 (68%)	12 (48%)	7 (28%)
1.5	5	5 (100%)	5 (100%)	2 (40%)	0 (0%)	0 (0%)
0.5	9	9 (100%)	7 (78%)	4 (44%)	3 (33%)	0 (0%)
Total for all categories	**295**	**238 (81%)**	**157 (53%)**	**92 (31%)**	**51 (17%)**	**32 (11%)**

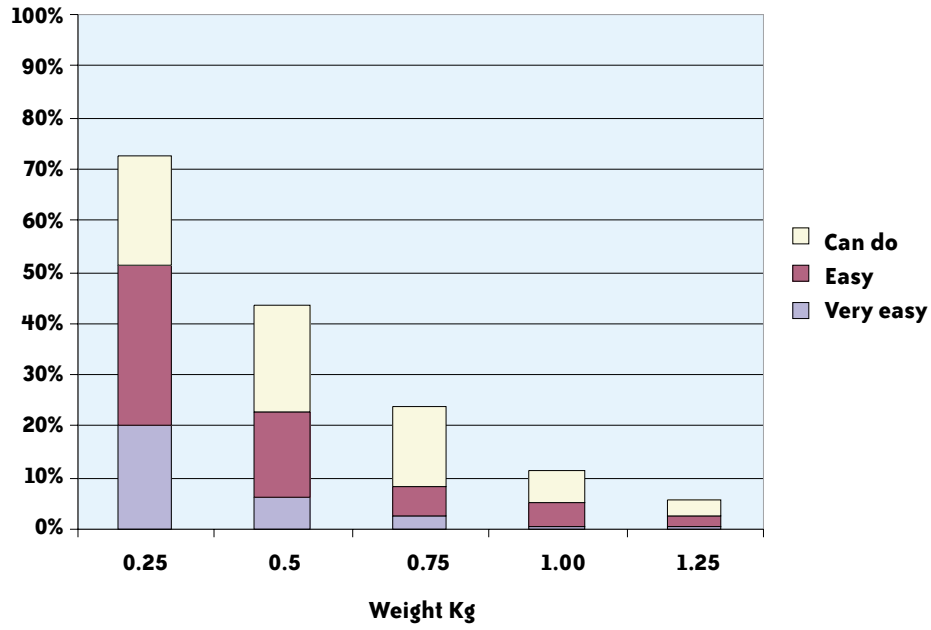
Vertical handle						
Dexterity category	No.	0.25Kg	0.5Kg	0.75Kg	1Kg	1.25Kg
10.5	19	10 (53%)	7 (37%)	3 (16%)	2 (11%)	0 (0%)
9.5	23	11 (48%)	6 (26%)	4 (17%)	4 (17%)	3 (13%)
8	30	17 (57%)	7 (23%)	6 (20%)	4 (13%)	3 (10%)
7	34	28 (82%)	18 (53%)	10 (29%)	3 (9%)	2 (6%)
6.5	62	48 (77%)	35 (56%)	21 (34%)	12 (19%)	5 (8%)
5.5	42	39 (93%)	30 (71%)	17 (40%)	10 (24%)	4 (10%)
4	26	24 (92%)	17 (65%)	8 (31%)	5 (19%)	3 (12%)
3	20	17 (85%)	16 (80%)	11 (55%)	6 (30%)	4 (20%)
2	25	23 (92%)	22 (88%)	20 (80%)	9 (36%)	10 (40%)
1.5	5	5 (100%)	4 (80%)	4 (80%)	2 (40%)	1 (20%)
0.5	9	9 (100%)	9 (100%)	4 (44%)	2 (22%)	2 (22%)
Total for all categories	**295**	**231 (78%)**	**171 (58%)**	**108 (37%)**	**59 (21%)**	**37 (13%)**

3.5.5 Estimated numbers (1000s) of people with dexterity impairments in Great Britain according to the amount lifted with one hand using a horizontal handle and vertical handle

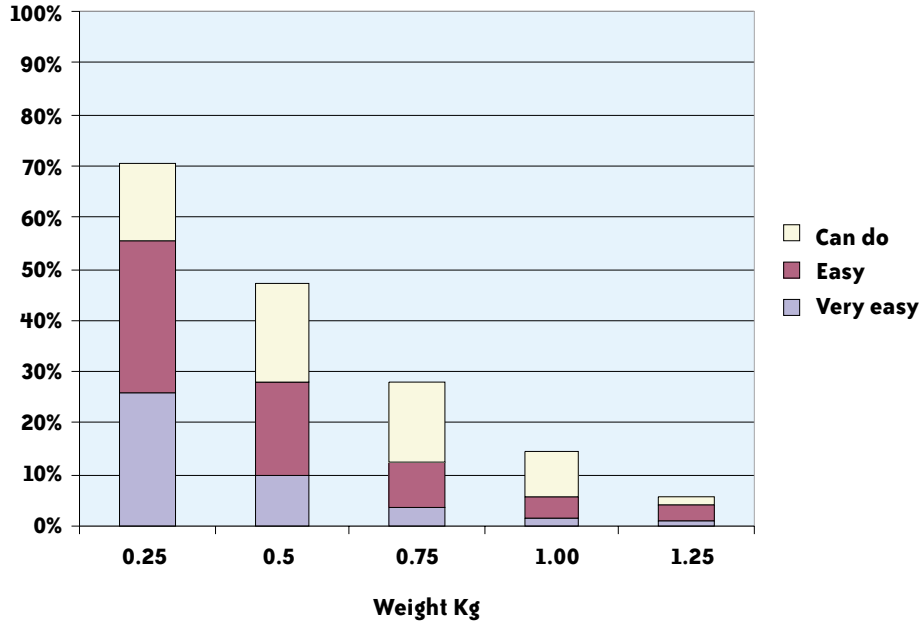
Horizontal handle					
	0.25Kg	0.5Kg	0.75Kg	1Kg	1.25Kg
Cannot do	288	648	1,021	1,271	1,411
Very difficult	175	294	255	209	165
Can do	353	347	256	104	49
Easy	520	283	97	82	40
Very easy	336	100	44	7	7
Vertical handle					
	0.25Kg	0.5Kg	0.75Kg	1Kg	1.25Kg
Cannot do	325	665	970	1,172	1,376
Very difficult	165	219	232	260	200
Can do	256	319	265	147	24
Easy	495	305	142	68	56
Very easy	431	163	63	25	16

3.5.6 Estimated percentage of people with dexterity impairments in Great Britain able to lift different weights using a horizontal and vertical handle

Horizontal



Vertical



Chapter 4
Finger grasp and pull strength

4.1 DESCRIPTION

The maximum pulling strength that can be applied with one-handed grasping of tabs with different widths using the thumb and finger only, and on blocks of different thickness, using the thumb and two fingers.

4.2 METHOD

The participant stood[5] (ambulant persons) or sat (wheelchair users) adopting an otherwise free posture. The participant was asked to grasp the tab or block with one hand and apply maximum pulling strength. In the case of the 6, 10 and 40mm tabs the participant was asked to use the thumb and forefinger in a pinching manner. With the blocks, the participant was asked to use a lateral pinch using the thumb and side of the forefinger. The maximum force, which was automatically shown in a visual display, was recorded. The action was repeated twice more.

4.3 EQUIPMENT

4.3.1 Tabs

Tabs 6, 10 and 40 mm wide and 2 mm thick were each clamped between two metal plates so that 30 mm of material protruded. The plates in turn were attached to a Mecmesin precision force gauge horizontally mounted.

4.3.2 Blocks

Blocks of 20 and 40 mm thickness were attached to a Mecmesin precision force gauge horizontally mounted.

[5]In a few cases ambulant participants preferred to sit.

4.4 ANALYSIS

4.4.1 Tabs

4.4.1.1 Effect of disability

The mean values of pull force for the non-disabled group were approximately twice that of the disabled group (see Tables 4.5.1.1 and 4.5.1.2). The non-disabled group performed significantly better than the disabled group at the p<.01 level.

4.4.1.2 Effect of impairment severity

This analysis was only concerned with those participants who used a lateral (thumb against side of the finger) grip, as opposed to a finger pinch grip since the majority of the sample used this grip (see Section 4.4.1.4).

The amount of pull force that could be applied (as indicated in the mean values), was found to be inversely related to the impairment severity. Significant differences were found between the majority of severity categories (see Table 4.5.1.1 and Table 3, Appendix 2).

4.4.1.3 Effect of tab width

The width of the tab determined the amount of force that could be applied. Increasing tab width generated higher pulling strength (see Tables 4.5.1.1 and 4.5.1.2). Correlation coefficients are also shown in Table 5, Appendix 2.

4.4.1.4 Effect of finger pinch vs lateral pull (small tabs)

On the small tab pull tasks the participants were asked to pinch the tabs between the tips of their thumb and finger. Very few people managed to pinch and pull either because they found it uncomfortable, ineffective, or physically impossible due to the nature of their disability. Further investigation revealed that there was a significant difference between the performance of individuals using finger pinch and those using lateral pull. The lateral pull group's forces were significantly higher (p = 0.0003)[6] .

Type of grip	6mm tab (N)					10mm tab (N)				
	No.	Mean	S.D.	Min	Max	No.	Mean	S.D.	Min	Max
Finger pinch	51	14.76	9.17	2.20	48.30	51	17.87	10.84	2.30	51.50
Lateral finger/thumb	141	21.36	14.60	1.60	85.50	141	24.96	16.82	1.60	91.00

4.4.1.5 Estimated numbers (1000s) of people with dexterity impairments in Great Britain according to the pull strength that can be applied for three tab width

Based on the results of this sample estimates were made using the OPCS results of the total number of people with dexterity impairments, with different pull strength capabilities for different size tab widths (see Table 4.5.1.3).

[6]For description of statistical definitions see Appendix 2, p49..

4.4.1.6 Proportion of persons with dexterity impairments capable of exerting different pulling strengths when grasping tabs of different widths

From these results the proportion of persons with dexterity impairments who are accommodated with different pull forces can be calculated for each of the three tab widths (see Chart 4.5.1.4).

4.4.2 Blocks

4.4.2.1 Effect of sitting vs standing (20 mm and 40 mm blocks)

The difference between sitting and standing for this task was investigated. Surprisingly wheelchair users performed marginally better than ambulant individuals. However, the difference was not significantly large so for the purposes of further analysis the two groups were combined.

	20mm Block (N)					40mm Block (N)				
	No.	**Mean**	**S.D.**	**Min**	**Max**	**No.**	**Mean**	**S.D.**	**Min**	**Max**
Wheelchair user	114	38.30	28.01	1.00	121.20	113	39.42	28.76	2.60	119.70
Seated ambulant	49	37.09	27.06	2.20	145.20	49	40.62	29.65	4.50	165.30
Ambulant	125	33.58	18.25	3.30	92.70	125	36.57	20.06	3.50	116.00

4.4.2.2 Effect of disability

The means of pull force for the non-disabled group were approximately twice that of the disabled group (see Tables 4.5.2.1 and 4.5.2.2).

Non-disabled participants performed better than disabled participants for all tab widths at a significance level of $p<0.01$.

4.4.2.3 Effect of impairment severity

The amount of pull force that could be applied (as indicated by the mean values), was found to be inversely proportional to the impairment severity (see Table 4.5.2.1 and Table 4, Appendix 2).

Significant differences were found between all of the severity categories.

4.4.2.4 Effect of block thickness

The thickness of the grasping medium affected the amount of pull force that could be applied. Increases in thickness generated higher pulling strength (Table 4.5.2.1). This result was significant at the $p<0.01$ level. Correlation coefficients are also shown in Table 6, Appendix 2.

4.4.2.5 Estimated numbers (1000s) of people with dexterity impairments in Great Britain according to the pull strength that can be applied for two block thicknesses

Based on the results of this sample estimates were made using the OPCS results of the total number of people with dexterity impairments, with different pull strength capabilities for different size block thicknesses (see Table 4.5.2.3).

4.4.2.6 Proportion of persons with dexterity impairments capable of exerting different pulling strengths when grasping blocks of different thicknesses

From these results the proportion of persons with dexterity impairments who are accommodated with different pull forces can be calculated for each of the two block thicknesses (see Chart 4.5.2.4).

4.5 RESULTS

4.5.1 Tabs

4.5.1.1 Disabled participants

OPCS Dexterity	6mm tab (N)					10mm tab (N)					40mm tab (N)				
	No.	Mean	S.D.	Min	Max	No.	Mean	S.D.	Min	Max	No.	Mean	S.D.	Min	Max
10.50	8	11.49	8.38	2.60	26.60	8	13.96	11.68	4.20	35.50	19	17.54	10.21	2.00	39.90
9.50	11	8.90	6.85	1.80	23.40	11	11.85	11.50	1.60	39.70	20	14.39	9.22	3.70	35.40
8.00	23	12.51	10.75	1.60	37.20	23	13.01	9.19	2.30	36.90	29	18.68	12.37	3.10	47.20
7.00	23	18.64	9.59	3.50	40.50	23	22.73	13.11	4.20	55.30	34	31.14	23.41	5.10	99.90
6.50	36	17.66	11.43	4.70	51.50	36	20.78	12.95	5.50	63.10	60	32.64	18.78	5.10	97.80
5.50	29	24.21	12.72	6.00	47.50	29	28.31	14.15	9.50	55.20	41	34.50	20.00	9.80	91.90
4.00	21	21.76	14.32	5.80	48.30	21	25.45	17.22	6.20	60.90	24	30.56	20.82	4.50	101.30
3.00	19	23.52	19.85	5.50	85.50	19	28.24	22.55	4.70	91.00	20	38.35	22.29	6.40	88.40
2.00	5	31.00	11.05	19.80	44.30	5	36.24	16.19	19.10	56.10	23	46.98	21.54	1.70	87.60
1.50	3	29.87	10.25	18.90	39.20	3	39.93	5.30	35.10	45.60	5	42.34	14.82	25.60	57.80
0.50	5	17.60	5.85	10.50	24.10	5	23.24	11.29	12.10	42.30	9	33.51	16.36	12.90	67.70
Total Overall Range	183					183					284				
		19.02	13.19				22.52	15.50				30.59	20.33		
				1.60	85.50				1.60	91.00				1.70	101.30

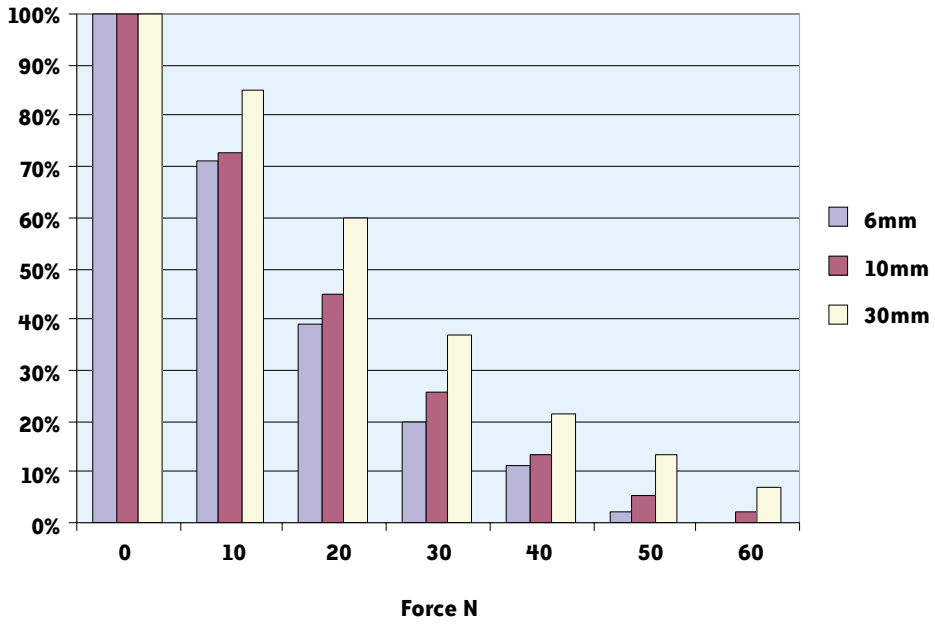
4.5.1.2 Non-disabled participants

6mm tab (N)						10mm tab (N)					40mm tab (N)				
	No.	Mean	S.D.	Min	Max	No.	Mean	S.D.	Min	Max	No.	Mean	S.D.	Min	Max
	91.00	36.60	14.67	6.40	73.10	120.00	41.54	16.86	5.60	79.40	120.00	66.94	33.25	7.90	156.80

4.5.1.3 Estimated numbers (1000s) of people with dexterity impairments in Great Britain according to the pull strength that can be applied for three tab width

Pull force (N)											
Tab widths	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
6 mm	1672	1190	649	333	185	33	4	4	4	0	0
10 mm	1672	1217	753	433	221	90	35	9	4	4	0
40 mm	1672	1418	1006	616	355	224	118	81	36	18	2

4.5.1.4 Proportion of persons with dexterity impairments capable of exerting different pulling strengths when grasping tabs of different widths



4.5.2 Blocks

4.5.2.1 Disabled participants

OPCS Dexterity	20mm Block (N)					40mm Block (N)				
	No.	Mean	S.D.	Min	Max	No.	Mean	S.D.	Min	Max
10.50	19	20.03	13.46	1.00	45.30	18	21.19	12.62	5.70	50.90
9.50	22	17.43	11.99	5.70	55.60	22	17.27	12.78	4.90	61.20
8.00	29	22.52	17.13	3.30	88.90	29	24.76	18.54	3.50	86.10
7.00	34	39.89	29.56	7.70	145.20	34	41.84	32.61	6.10	165.30
6.50	60	37.37	22.65	4.00	121.20	60	41.59	24.60	5.40	119.70
5.50	41	38.38	17.45	12.60	83.30	41	42.73	21.07	13.00	104.80
4.00	25	35.21	22.39	9.60	106.90	25	36.85	21.90	14.60	92.40
3.00	20	48.09	28.83	6.70	101.50	20	49.82	28.45	4.50	111.00
2.00	25	53.64	25.91	4.00	100.30	25	52.97	26.71	2.60	116.00
1.50	5	51.10	9.77	39.10	62.80	5	53.68	15.05	36.80	75.50
0.50	9	40.19	17.48	16.50	67.70	9	40.80	17.56	13.80	65.20
Total Overall Range	289					288				
		35.95	23.80				38.29	25.27		
				1.00	145.20				2.60	165.30

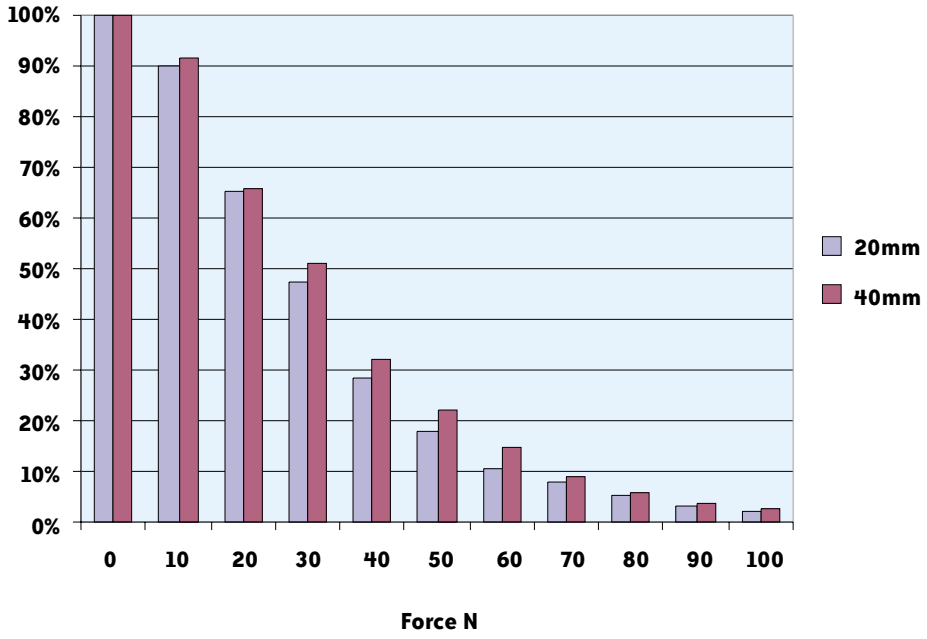
4.5.2.2 Non-disabled participants

20mm Block (N)					40mm Block (N)				
No.	Mean	S.D.	Min	Max	No.	Mean	S.D.	Min	Max
120.00	66.05	33.14	15.30	259.10	120.00	70.48	32.39	15.00	161.10

4.5.2.3 Estimated numbers (1000s) of people with dexterity impairments in Great Britain according to the pull strength that can be applied for two block thicknesses

Pull force (N)														
Block thickness	0	10	20	30	40	50	60	70	80	90	100	120	130	140
20 mm	1672	1507	1093	792	475	299	176	132	90	53	33	12	12	3
40 mm	1672	1528	1098	850	539	371	245	145	95	65	44	28	3	3

4.5.2.4 Proportion of persons with dexterity impairments capable of exerting different pulling strengths when grasping tabs of different widths



Chapter 5
Ring pull strength

5.1 DESCRIPTION

The maximum static pulling strength that can be applied when pulling on rings of different diameters with one finger.

5.2 METHOD

The participant stood[7] (ambulant persons) or sat (wheelchair users) adopting an otherwise free posture. The participant's elbow height (ie with the elbow bent and the forearm horizontal) was measured and the height of the ring pull set to this height.

Using the most preferred finger of the preferred hand the participant was asked to exert maximum pulling strength for the smallest ring. This was repeated three times. The whole process was then repeated with the medium sized ring and then the largest ring in that order. The maximum force, which was automatically shown in a visual display, was recorded. The action was repeated twice more.

5.3 EQUIPMENT

A Mecmesin force gauge (Model No. AFG 500N) was horizontally mounted on a height adjustable rig. Each of 3 different internal diameter rings (17, 20 and 30 mm diameter) could be attached to the force shaft of the meter. The rig was arranged in such a way as to allow wheelchair users to approach close to the force gauge.

[7] In a few cases ambulant participants preferred to sit.

5.4 ANALYSIS

5.4.1 Effect of disability

The mean strength values for the non-disabled groups were approximately twice those of the disabled group (see Tables 5.5.1 and 5.5.2). The non-disabled group performed significantly better than the disabled group at the $p<0.01$ level.

5.4.2 Effect of impairment severity

Pull force that could be applied with each of the three diameter rings was inversely related to severity of impairment (see Table 5.5.1). Significant differences were found within the severity categories with very few exceptions (see Table 7, Appendix 2).

5.4.3 Effect of ring diameter

Ring diameter affected the amount of pull force that could be applied. The maximum pull strength that could be applied increased significantly with increases in ring pull diameter (see Table 5.5.1). Correlation coefficients are shown in Table 8, Appendix 2.

5.4.4 Estimation of incidence of different levels of ring pull strength for people with dexterity impairments

Based on the results of this sample estimates were made using the OPCS results of the total number of people with dexterity impairments, with different strength capabilities for different size ring pulls (see Table 5.5.3).

5.4.5 Proportion of persons with dexterity impairments capable of exerting different pulling strengths when grasping ring pulls of different diameters

From these results the proportion of persons with dexterity impairments who are accommodated with different pull forces can be calculated for each of the three ring diameters (see Chart 5.5.4).

5.5 RESULTS

5.5.1 Disabled participants

OPCS Dexterity	17mm Ring (N)					20mm Ring (N)					30mm Ring (N)				
	No.	Mean	S.D.	Min	Max	No.	Mean	S.D.	Min	Max	No.	Mean	S.D.	Min	Max
10.50	19	26.42	15.58	6.50	70.30	19	30.52	16.48	6.60	63.20	19	47.75	48.49	7.70	232.00
9.50	20	15.57	13.36	3.80	66.70	20	21.62	17.81	5.30	78.90	20	23.75	16.13	4.80	73.00
8.00	26	23.84	25.00	1.80	119.70	29	26.92	28.51	2.70	148.20	29	29.08	27.55	3.30	131.40
7.00	34	33.18	27.07	5.40	107.20	34	44.86	39.12	4.40	183.20	34	48.74	41.01	8.30	203.80
6.50	59	34.30	21.74	4.50	103.30	60	46.33	35.59	5.60	195.10	60	52.02	39.06	7.50	193.00
5.50	41	38.91	24.05	6.20	98.70	41	50.93	27.60	7.20	113.00	42	55.30	28.43	9.40	119.90
4.00	25	34.69	19.14	9.90	80.40	25	45.51	23.16	13.20	95.70	25	47.86	25.30	10.00	105.70
3.00	20	47.09	28.52	10.30	110.50	20	63.85	41.34	10.10	154.80	20	64.54	38.97	10.70	138.80
2.00	23	48.69	29.91	2.10	110.30	23	70.18	54.73	1.60	250.10	23	75.04	55.68	2.40	215.90
1.50	5	51.42	8.75	42.10	64.90	5	75.74	39.37	49.20	144.00	5	81.80	39.07	49.40	148.90
0.50	9	44.12	13.89	14.00	59.00	9	55.81	22.04	13.10	79.70	9	62.80	23.87	18.90	92.50
Total Overall Range	281					285					286				
		34.75	24.36				45.95	35.79				50.75	38.54		
				1.80	119.70				2.70	250.10				2.40	232.00

5.5.2 Non-disabled participants

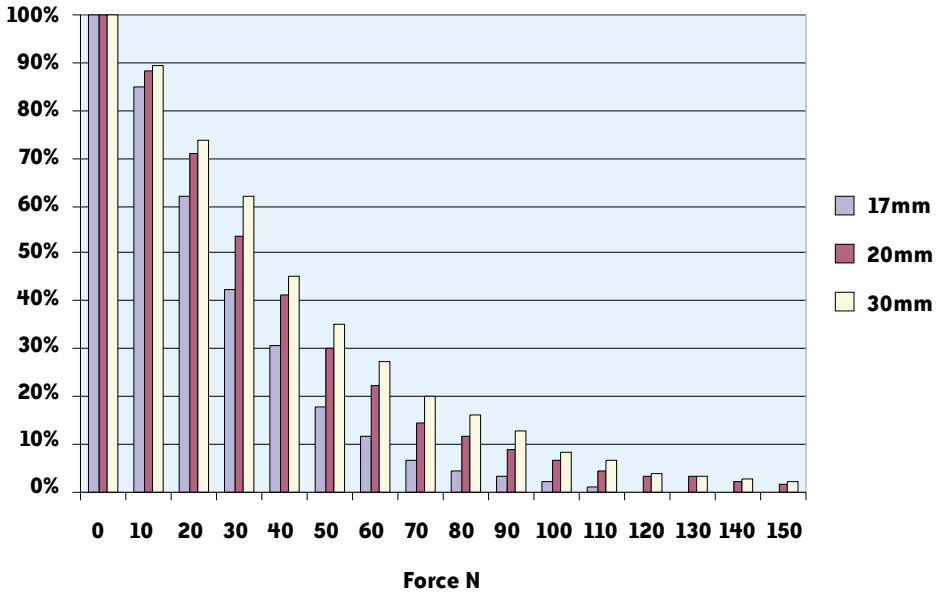
	17mm Ring (N)					20mm Ring (N)					30mm Ring (N)				
	No.	Mean	S.D.	Min	Max	No.	Mean	S.D.	Min	Max	No.	Mean	S.D.	Min	Max
	118	65.847	29.488	6.1	139.1	118	92.868	55.909	8.2	275.7	118	101.92	63.682	8.9	324.7

5.5.3 Estimated numbers (1000s) of people with dexterity impairments in Great Britain according to the pull strength that can be applied for three different diameter rings

	Pull force									
Ring pull size	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**
17 mm	1672	1417	1034	710	509	295	198	114	79	60
20 mm	1672	1477	1187	899	694	509	370	241	195	148
30 mm	1672	1495	1231	1037	760	593	457	335	266	216

	Pull force									
Ring pull size	**130**	**140**	**150**	**160**	**170**	**180**	**190**	**200**	**210**	**220**
17 mm	0	0	0	0	0	0	0	0	0	0
20 mm	52	35	24	17	17	17	14	5	5	5
30 mm	60	46	39	39	39	39	25	16	13	9

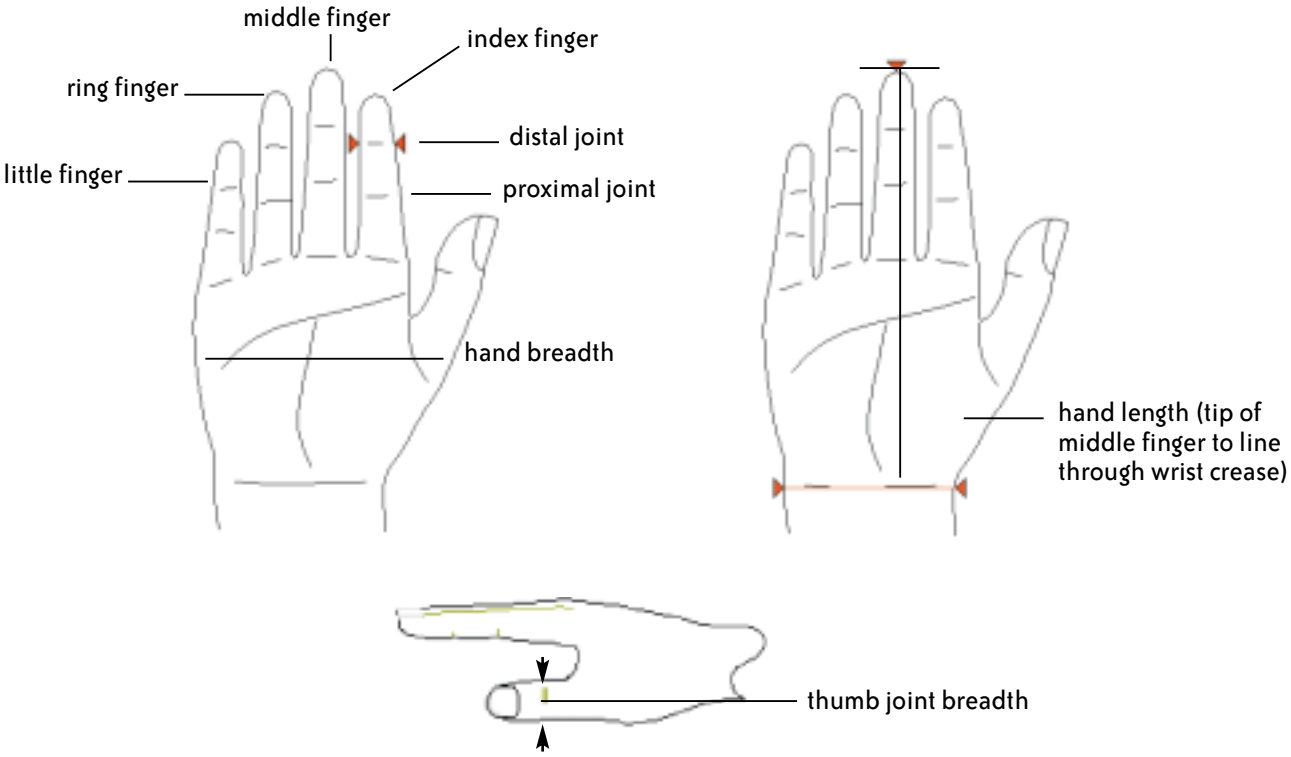
5.5.4 Proportions of people with dexterity impairments capable of exerting different pulling strength when grasping 'ring pulls' of different diameter



Chapter 6
Finger/thumb dimensions

6.1 DESCRIPTION

The breadth of each finger and the depth of the thumb at the proximal and distal joints and the handbreadth and length[8] .



6.2 METHOD

The participant placed their hand palm down, spreading the fingers if possible, on a flat board that had a grid marked in 10 mm intervals. Using a camera set at fixed distance above the board, a film record was made using 35 mm transparency film. Two camera records were made. The whole procedure was repeated with the other hand. The film was subsequently projected onto a screen and measurements made of the finger and thumb dimensions and of the grid scale factor employed in the projection.

[8]Reproduced from PeopleSize with permission of Friendly Systems Ltd.

6.3 EQUIPMENT

A small rig (resembling a tripod) with a flat base onto which was marked a 10 mm square grid. At the top of the tripod a camera was mounted. The base was also marked with an outline of a hand.

6.4 ANALYSIS

6.4.1 Effect of disability

No significant difference was found between the hand dimensions of disabled participants and non-disabled participants.

6.4.2 Effect of impairment severity

No significant association between hand dimension and severity of impairment was found.

6.4.3 Hand dimension

The relevant dimensions of hands, fingers and thumb for disabled and non-disabled participants are shown in Tables 6.5.1 and 6.5.2, together with 5th, 50th and 95th %ile values (see Tables 6.5.3 and 6.5.4).

6.5 RESULTS

6.5.1 Hand dimensions of dexterity disabled participants

Hand dimension		Right hand (mm)					Left hand (mm)				
		No.	Mean	S.D.	Min	Max	No.	Mean	S.D.	Min	Max
Hand	Length	253	173.8	17.3	114.0	228.0	262.0	173.8	17.9	115.0	226.0
	Breadth	261	90.9	8.3	61.3	123.7	268.0	90.0	8.0	64.0	115.6
Index finger	Proximal joint breadth	257	21.7	2.2	15.0	29.6	261.0	21.8	2.5	2.0	28.5
	Distal joint breadth	255	18.8	2.3	13.0	39.0	260.0	18.7	1.9	14.2	24.3
Second finger	Proximal joint breadth	256	22.0	2.2	14.8	28.9	263.0	21.7	2.5	1.0	31.3
	Distal joint breadth	255	18.5	1.8	11.9	24.3	262.0	18.2	1.8	14.0	23.4
Ring finger	Proximal joint breadth	254	20.7	2.1	15.0	29.0	260.0	20.1	2.1	3.2	25.5
	Distal joint breadth	253	17.2	2.0	1.2	23.4	262.0	16.8	1.7	13.5	23.0
Little finger	Proximal joint breadth	249	18.2	2.2	1.9	23.7	255.0	17.5	1.7	13.0	22.8
	Distal joint breadth	248	16.0	1.7	10.5	21.1	254.0	15.4	1.7	9.8	20.4
Thumb	Distal joint breadth	224	21.9	2.2	16.4	28.3	218.0	22.6	2.2	17.8	28.3

6.5.2 Hand dimensions of non-disabled participants

Hand dimension		Right hand (mm)					Left hand (mm)				
		No.	Mean	S.D.	Min	Max	No.	Mean	S.D.	Min	Max
Hand	Length	113	176.5	14.8	127.0	229.3	106.0	175.6	14.3	142.9	208.0
	Breadth	112	90.5	8.8	57.6	115.9	108.0	89.9	7.9	63.9	115.5
Index finger	Proximal joint breadth	113	21.0	2.0	16.2	28.5	107.0	20.9	1.9	15.1	24.9
	Distal joint breadth	112	18.3	1.8	14.8	25.7	108.0	18.1	1.8	13.1	22.4
Second finger	Proximal joint breadth	113	21.2	2.0	15.7	30.9	107.0	20.8	1.9	14.4	25.0
	Distal joint breadth	112	18.0	1.7	14.3	25.4	107.0	17.6	1.7	12.9	21.9
Ring finger	Proximal joint breadth	113	20.2	1.9	15.0	28.3	107.0	19.3	1.9	14.1	23.9
	Distal joint breadth	112	16.9	1.6	13.1	23.5	108.0	16.4	1.6	11.6	21.0
Little finger	Proximal joint breadth	113	17.7	1.9	13.9	25.0	107.0	16.9	1.7	11.4	22.3
	Distal joint breadth	112	15.7	1.6	12.4	22.8	108.0	15.1	1.5	11.1	19.4
Thumb	Distal joint breadth	105	21.6	2.2	17.6	28.7	100.0	21.8	2.3	16.8	27.7

6.5.3 Percentiles - disabled participants

Hand dimension		Men %iles(mm)			Women %iles(mm)			Combined %iles(mm)		
		5th	50th	95th	5th	50th	95th	5th	50th	95th
Hand	Length	89.6	178.0	209.2	84.7	167.2	191.1	85.9	170.1	201.7
	Breadth	48.4	94.1	108.0	43.4	87.4	96.5	44.1	88.5	102.6
Index finger	Proximal joint breadth	11.1	22.7	26.1	10.3	20.6	23.7	10.6	20.9	25.2
	Distal joint breadth	10.0	19.2	22.6	8.7	18.0	20.6	9.0	18.1	22.0
Second finger	Proximal joint breadth	11.5	22.7	26.9	10.5	20.7	23.7	10.5	21.1	24.7
	Distal joint breadth	9.7	18.9	21.9	8.6	17.3	20.1	8.7	17.7	21.3
Ring finger	Proximal joint breadth	10.6	20.7	24.6	9.8	19.2	22.2	10.0	19.6	23.0
	Distal joint breadth	9.0	17.5	20.5	7.9	16.2	18.5	8.2	16.5	19.9
Little finger	Proximal joint breadth	9.0	18.1	21.5	8.4	16.9	19.5	8.5	17.1	20.6
	Distal joint breadth	8.0	16.4	19.3	7.3	14.8	17.0	7.4	15.1	18.1
Thumb	Distal joint breadth	11.5	22.7	27.0	9.6	21.0	24.2	10.0	21.2	25.6

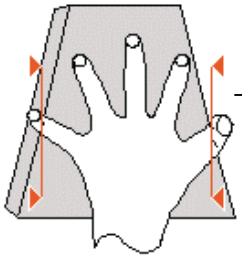
6.5.4 Percentiles – non-disabled participants

Hand dimension		Men %iles(mm)			Women %iles(mm)			Combined %iles(mm)		
		5th	50th	95th	5th	50th	95th	5th	50th	95th
Hand	Length	90.4	182.0	197.7	124.1	169.0	197.4	92.2	174.9	198.0
	Breadth	48.1	95.4	103.6	59.9	86.8	98.8	48.2	88.4	103.3
Index finger	Proximal joint breadth	11.3	21.4	24.0	15.0	20.2	23.2	11.5	20.5	24.0
	Distal joint breadth	9.9	18.7	21.7	13.1	17.4	20.2	10.3	17.6	21.2
Second finger	Proximal joint breadth	11.4	21.4	24.9	14.6	20.2	22.5	11.5	20.4	24.5
	Distal joint breadth	9.4	18.2	21.5	12.7	17.0	20.1	9.6	17.3	20.7
Ring finger	Proximal joint breadth	10.4	20.1	23.4	13.9	18.8	21.7	10.6	19.3	23.0
	Distal joint breadth	9.3	17.2	20.2	11.3	15.8	18.6	9.0	16.3	19.3
Little finger	Proximal joint breadth	9.5	17.9	20.7	11.8	16.5	19.6	9.5	17.0	20.2
	Distal joint breadth	8.2	16.0	18.2	10.8	14.6	17.4	8.4	15.0	17.8
Thumb	Distal joint breadth	11.1	22.7	26.0	14.2	20.5	24.7	11.3	21.3	25.4

Chapter 7
Hand grip span

7.1 DESCRIPTION

The maximum grip span between the thumb and any preferred finger.

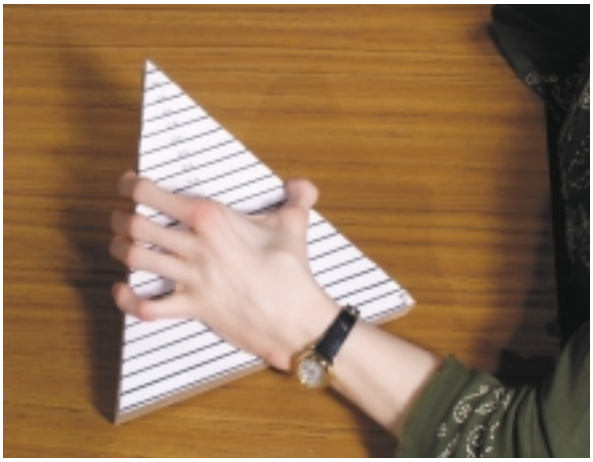


7.2 METHOD

The participant placed the palm of their hand onto the face of the triangular surface, gripping the edges at the maximum possible width consistent with a usable grip. The width at which the finger and thumb contacted the edge of the surface was recorded using the 10 mm interval scale marked on the surface. This procedure was repeated three times and then the whole procedure repeated with the other hand.

7.3 EQUIPMENT

A flat wooden triangular plate 30 mm thick and varying in width between zero and 220 mm and marked with lines across the plate at 10 mm intervals.



7.4 ANALYSIS

7.4.1 Effect of disability

A significant difference was found between the hand grip span dimension of disabled participants and non-disabled participants at a level of $p<0.01$.

7.4.2 Effect of impairment severity

No significant association between the hand grip span dimension and severity of impairment was found.

7.4.3 Hand grip span dimension

The dimensions of the hand grip span for disabled and non-disabled participants is shown in Tables 7.5.1 and 7.5.2 together with 5th, 50th and 95th %ile values (see Tables 7.5.3 and 7.5.4).

7.4.4 Proportion of participants with different hand spans

The proportion of disabled and non-disabled participants with different hand spans is shown in Chart 7.5.5.

7.5 RESULTS

7.5.1 Hand grip span of dexterity disabled participants

Hand grip span of dexterity disabled participants (mm)					
Male	**No.**	**Mean**	**S.D.**	**Min**	**Max**
Left hand	78	72.13	23.48	22.57	141.10
Right hand	82	67.03	21.65	15.60	111.85
Left and right combined	160	69.51	22.63	15.60	141.10
Female					
Left hand	193	61.25	20.64	5.00	129.13
Right hand	198	61.95	20.13	7.71	111.03
Left and right combined	391	61.61	20.36	5.00	129.13
Male and female combined					
Left hand	271	64.38	22.01	5.00	141.10
Right hand	280	63.44	20.68	7.71	111.85
Left and right combined	551	63.90	21.33	5.00	141.10

7.5.2 Hand grip span of non-disabled participants

Hand grip span of non-disabled participants (mm)					
Male	**No.**	**Mean**	**S.D.**	**Min**	**Max**
Left hand	46	84.79	23.60	44.44	141.89
Right hand	46	83.63	20.32	45.97	130.87
Left and right combined	92	84.21	21.91	44.44	141.89
Female					
Left hand	79	71.31	18.88	27.50	120.56
Right hand	79	73.22	18.05	32.20	116.36
Left and right combined	158	72.26	18.44	27.50	120.56
Male and female combined					
Left hand	125	76.27	21.65	27.50	141.89
Right hand	125	77.05	19.50	32.20	130.87
Left and right combined	250	76.66	20.57	27.50	141.89

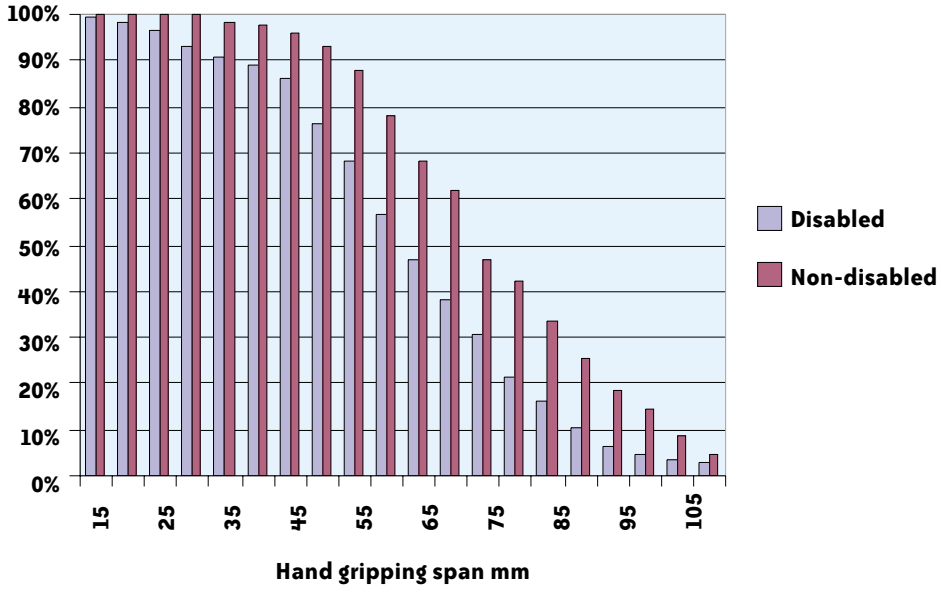
7.5.3 Pecentiles - disabled participants

	5th %ile (mm)	50 th %ile (mm)	95th %ile (mm)
Male			
Left hand	29.10	70.59	120.72
Right hand	24.80	68.70	98.56
Left and right combined	27.90	69.41	110.82
Female			
Left hand	28.18	60.00	93.59
Right hand	26.32	62.66	100.82
Left and right combined	27.66	61.38	97.60
Male and female combined			
Left hand	28.16	62.88	99.68
Right hand	25.61	63.84	100.81
Left and right combined	27.66	63.49	100.86

7.5.4 Percentiles - no-disabled participants

	5th %ile (mm)	50 th %ile (mm)	95th %ile (mm)
Male			
Left hand	47.90	87.00	120.87
Right hand	57.80	81.02	121.17
Left and right combined	50.72	83.57	123.75
Female			
Left hand	47.00	69.77	101.10
Right hand	43.66	72.74	103.01
Left and right combined	44.38	71.51	103.11
Male and female combined			
Left hand	46.18	74.48	113.89
Right hand	47.20	75.12	107.42
Left and right combined	46.37	74.70	110.07

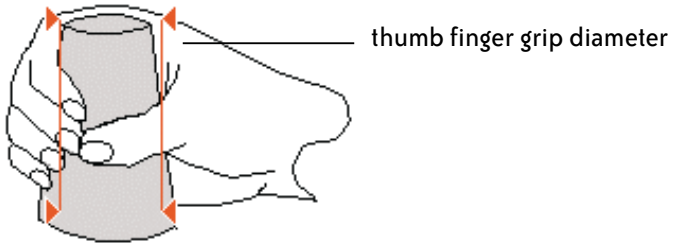
7.5.5 Proportions of people with dexterity disabilities and non-disabled people with different hand grip span



Chapter 8
Thumb-finger grasping diameter

8.1 DESCRIPTION

The maximum diameter that can be grasped with the thumb and middle finger when just in contact.

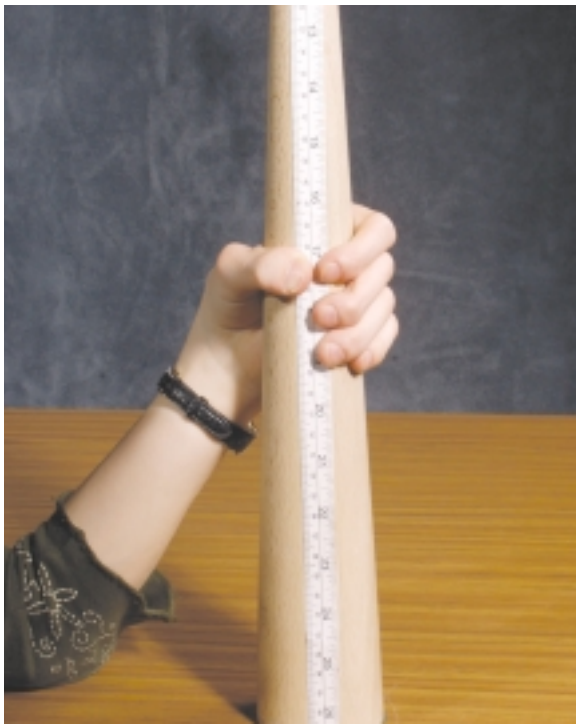


8.2 METHOD

The participant was asked to place their forefinger (or any suitable finger) and thumb around a conical cylinder so that the finger and thumb ends were in contact. They were then asked to slide their finger and thumb down the cone until they just start to separate. The diameter at which this occurred was read off the recorded scale on the side of the cone. The measure was repeated three times.

8.3 EQUIPMENT

A wooden cone varying in diameter from 20 to 65 mm with a scale along the side marked in mm intervals.



8.4 ANALYSIS

8.4.1 Effect of disability

A significant difference was found between the hand dimensions of disabled participants and non-disabled participants at a level of $p<0.01$.

8.4.2 Effect of impairment severity

No significant association between hand dimension and severity of impairment was found.

8.4.3 Thumb – finger grasping diameter

The dimensian of the thumb-finger grasping diameter for disabled and non-disabled participants together with 5th, 50th and 95th percentile values is shown on tables 8.5.1, 8.5.2, 8.5.3 and 8.5.4.

8.4.4 Proportions of participants with different thumb – finger grasping diameters

The proportion of disabled and non-disabled participants with different thumb – finger grasping diameters is shown in Chart 8.5.5.

8.5 RESULTS

8.5.1 Disabled

Finger - thumb grasping diameters of disabled participants (mm)					
Male	**No.**	**Mean**	**S.D.**	**Min**	**Max**
Left hand	62	39.08	7.87	26.00	53.00
Right hand	70	38.96	5.32	25.67	53.00
Left and right combined	132	39.01	6.63	25.67	53.00
Female					
Left hand	177	36.41	5.47	23.00	54.00
Right hand	180	36.40	5.33	22.27	52.51
Left and right combined	357	36.41	5.39	22.27	54.00
Male and female combined					
Left hand	239	37.10	6.24	23.00	54.00
Right hand	250	37.12	5.44	22.27	53.00
Left and right combined	489	37.11	5.84	22.27	54.00

8.5.2 Non-disabled

Finger - thumb grasping diameters of non-disabled participants (mm)					
Male	**No.**	**Mean**	**S.D.**	**Min**	**Max**
Left hand	46	41.09	4.72	33.17	55.83
Right hand	46	41.16	3.34	31.97	54.23
Left and right combined	92	41.12	3.93	31.97	55.83
Female					
Left hand	78	39.97	3.91	30.22	51.82
Right hand	77	40.03	5.28	32.30	49.12
Left and right combined	155	40.00	4.48	30.22	51.82
Male and female combined					
Left hand	124	40.38	4.24	30.22	55.83
Right hand	123	40.46	4.19	31.97	54.23
Left and right combined	247	40.42	4.21	30.22	55.83

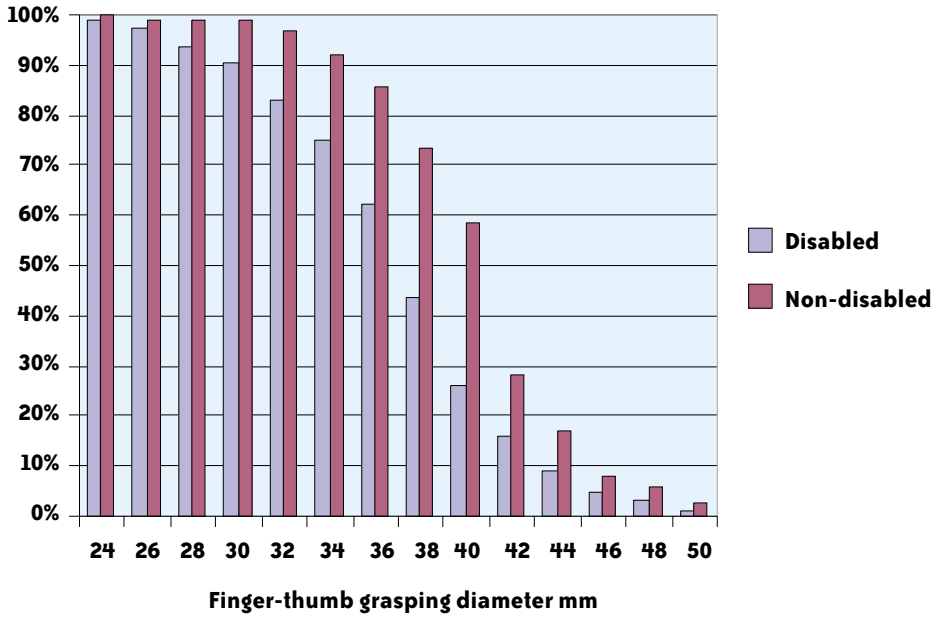
8.5.3 Percentile distribution of thumb - finger grasping diameter of disabled people

	5th %ile (mm)	50 th %ile (mm)	95th %ile (mm)
Male			
Left hand	33.48	40.28	48.90
Right hand	34.31	40.03	45.18
Left and right combined	33.90	40.27	47.29
Female			
Left hand	33.33	44.14	46.76
Right hand	33.57	40.47	49.43
Left and right combined	33.54	40.20	48.35
Male and female combined			
Left hand	33.40	40.18	48.13
Right hand	33.94	40.30	47.99
Left and right combined	33.60	40.27	48.08

8.5.4 Percentile distribution of thumb - finger grasping diameter of non-disabled people

	5th %ile (mm)	50 th %ile (mm)	95th %ile (mm)
Male			
Left hand	28.68	39.17	49.80
Right hand	30.00	39.20	47.90
Left and right combined	29.13	39.17	49.59
Female			
Left hand	26.65	43.04	44.39
Right hand	27.19	37.13	45.34
Left and right combined	26.71	37.00	44.98
Male and female combined			
Left hand	26.67	37.27	45.56
Right hand	28.09	37.67	46.31
Left and right combined	26.93	37.49	46.31

8.5.5 Proportions of people with dexterity disabilities and non-disabled people with different thumb / finger grasping diameter



Chapter 9
Elbow height

9.1 DESCRIPTION

Height to underside of horizontally flexed forearm above the ground.

9.2 METHOD

Incidental to many of the strength measurements, elbow height was measured. With the participant standing upright (or sitting upright) and with the elbow bent at right angles, the height of the underside of the elbow to the ground was measured by means of a steel measuring tape.

9.3 EQUIPMENT

A retractable steel tape.

9.4 ANALYSIS

No analysis other than descriptive statistics was considered necessary.

9.5 RESULTS

Elbow height – of dexterity disabled participants and non-disabled participants (mm)

	No.	Mean	S.D.	Min	Max
Wheelchair participants	115	707.35	53.8	550	880
Ambulant disabled participants	135	1020.27	77.33	700	1190
Non-disabled participants	111	1061.80	62.30	925	1190

Chapter 10
Concluding remarks

The results of the survey demonstrate considerable differences between the strength capabilities of disabled people and non-disabled people. In all of the tests the strength capabilities of non-disabled people was between two and three times that of disabled people. This poses a considerable challenge to designers and manufacturers of consumer products if they are to produce products that disabled people will be able to use with the same degree of ease and convenience and with a similar safety level as that expected by non-disabled people.

For example exerting twisting forces as when unscrewing the lids of screw top jars will need to be limited to a torque as little as 0.25 to 0.5 Nm if a sizeable proportion of those with dexterity disabilities are to be accommodated. Similarly opening packaging that involves pulling on small tabs will need to be restricted to pull force levels of approximately 5 N if again, a sizeable majority of disabled people are to be catered for.

While the results of the survey showed little significant difference between the hand / finger sizes of disabled people as compared with non-disabled people, the functional anthropometric characteristics were significantly different. For example the hand span of disabled people i.e. the maximum grip capability between the thumb and any finger, than that of non-disabled people. This was also true for the maximum grip diameter - i.e. with the finger and thumb touching.

The previous report 'A study of the difficulties disabled people have when using everyday consumer products' described the difficulties disabled people have with consumer products and demonstrated that very large numbers of disabled people are involved. This report confirms that large numbers of disabled people do indeed have very low strength capabilities and if their demands are to be met, radically different solutions in consumer products interface design are required.

The experience with this project demonstrated the feasibility of collecting representative data on the strength capabilities and hand anthropometric characteristics of people with disabling conditions resulting in restricted reach and dexterity. The data collected is reliable and validated and as such if applied appropriately to the design of consumer products will make them easier and safer to use by disabled people.

Chapter 11
References

DTI. 2000. *A study of the difficulties that disabled people have when using everyday consumer products.* URN 00/1070 Department of Trade and Industry, London.

Copies of the above publication is available from:
DTI Publications
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London
SW1W 8YT

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Email dtipubs@eclogistics.co.uk
Internet www.dti.gov.uk

Chapter 12
Acknowledgements

The Department would like to acknowledge the considerable help that Robert Feeney Associates received from the Department of Rheumatology, Leicester Royal Infirmary, Leicester and the Department of Rehabilitation and Rheumatology, Royal National Hospital, Bath, who collaborated in this research. We would like to especially thank the very helpful medical and administrative staff of both hospitals and in particular Dr F Nichol, Leicester, and Dr A Clarke, Bath.

Appendix 1
Sampling & data collection methodology

1.0 SAMPLE

1.1 Disabled participants

The sample of disabled people were selected using a number of sources including the patients attending rheumatology and rehabilitation department's in various hospitals and people visiting day centres in the East Midlands area of the UK. The basic criteria for selection was that participants had some form of reaching and dexterity and manipulation impairment and were able to communicate in a cogent manner their subjective assessments of the levels of difficulty encountered when carrying out the different tests. The sample included people who were living in normal homes and also those who are living in sheltered accommodation but live to a certain degree independently.

The basis for categorising participants of that study was the Office of Population Censuses and Surveys (Martin et al 1988) study that reported on the prevalence and severity of disability amongst adults in England and Wales. The result described the number of adults with disabilities and rated the severity of each person's disability. In all there were twelve distinct categories including those concerned with physical ability, sensory ability, intellectual functioning and disfigurement. The categories of relevance to this study were Reaching and stretching and Dexterity. The severity rating used in the OPCS survey was used to score each individual according to their level of severity. Between 9 and 12 severity scores with equal intervals were used dependent on the category. With Dexterity for example, score 10.5 contained the most severely disabled people and score 0.5 the least disabled. The higher severity rating therefore, the more severely affected the person was by their disability in each of the categories. The statistics for the whole group of 315 participants are shown below.

												Total
Severity category	**10.5**	**9.5**	**8**	**7**	**6.5**	**5.5**	**4**	**3**	**2**	**1.5**	**0.5**	
Numbers	21	24	32	36	63	43	27	21	27	10	11	**315**

1.2 Non-disabled participants - control group

A sample of non-disabled people were selected randomly but including a wide age range in order to compare the results with the sample of disabled participants. The general statistics for the whole group of 95 participants are shown below.

1.3 National estimates based on RFA sample

In selecting subjects for the survey the aim was to ensure that all relevant disabilities and levels of severity within each disability were adequately represented in order that accurate estimates could be made of the incidence of different anthropometric measures and strength capabilities within the disabled population. Using the breakdown of severity levels for the relevant categories, as described in the OPCS survey estimates of the levels of the hand strength such national estimates were possible. These are described in the various relevant sections.

2.0 DATA COLLECTION METHODOLOGY

2.1 Measurements

Both strength and anthropometric measures of each participant was recorded. In addition, for disabled participants, assessments were made of the severity of their disability according to two categories namely reaching and stretching, and dexterity.

2.2 Procedures used

In the case of the direct strength measurements eg. those giving instrumented readings, subjects performed three strength exertions for each experimental condition. In the case of the lifting strength tests, with the addition of each weight, subjects were asked to rate the level of difficulty they experienced on a five-point scale. Participants were asked to apply their maximum strength at all times without undue or excessive discomfort. Subjects were given adequate rest in between exertions and the test was stopped for a longer period (or even permanently) if requested.

Subjects stood during the test unless they specifically requested to be seated, or were in a wheelchair. For the tab, block and ring pull strength measurements the test device was adjusted and positioned at each participant's elbow height. For the two-handed twisting strength test, subjects were free to choose the positioning of the jars. For the lifting tests, two work surface heights were used. 860 mm height was used for participants who stood. 740 mm height was used for those who were seated. These heights were based on the recommendations from trials conducted to determine sitting heights for disabled people (RFA, 1998). Subjects were encouraged to view the read-out of the instrument in order to provide some visual feedback of their effort.

For the anthropometric measures, subjects were simply asked to place their hands in turn on a measuring grid at which time a photograph was taken.

2.3 Equipment

Tab and block pull strength, ring pull strength were measured on a series of specially made devices attached to a Mecmesin™ Advanced Force Gauge (AFG 500N). Two-handed twisting strength was measured using strain gauges and precision voltmeters.

For the anthropometric measures single lens reflex cameras were used at fixed focal length.

2.4 Analysis

2.4.1 General

Participants were selected on the basis of two disabilities namely dexterity and reaching and stretching, since these were considered to be the only relevant categories of all the 13 OPCS categories. In many cases participants in this sample had both disabilities. For the purpose of estimating the number in the population with different strength capabilities it is necessary to know how many of the OPCS sample had only dexterity disability, how many had only reaching and stretching disabilities and how many had both. Unfortunately the OPCS sample does not provide such details.

To make estimates using both categories would lead to a gross overestimation of the number in the disabled population who had different strength capabilities since, as stated previously, most of this sample had both disabilities. For the purpose of analysis therefore one category had to be chosen. It was realised that this would result in an underestimation of the numbers with different strength capabilities but it was considered that this would be small.

In order to choose which category would be the most reliable the following analysis was carried out.

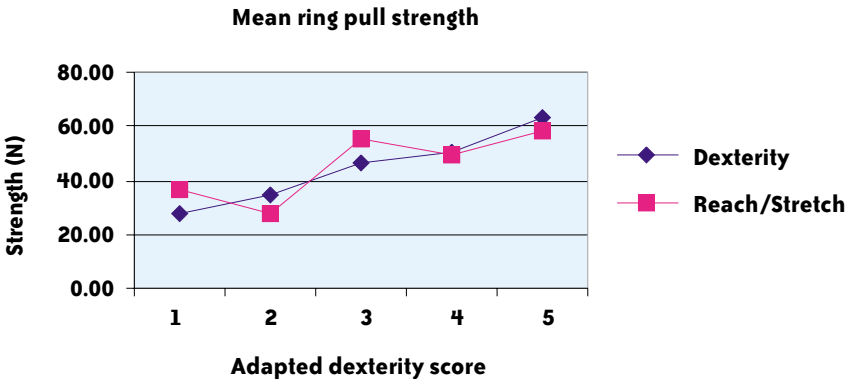
2.4.2 Choice of disability category for population estimates

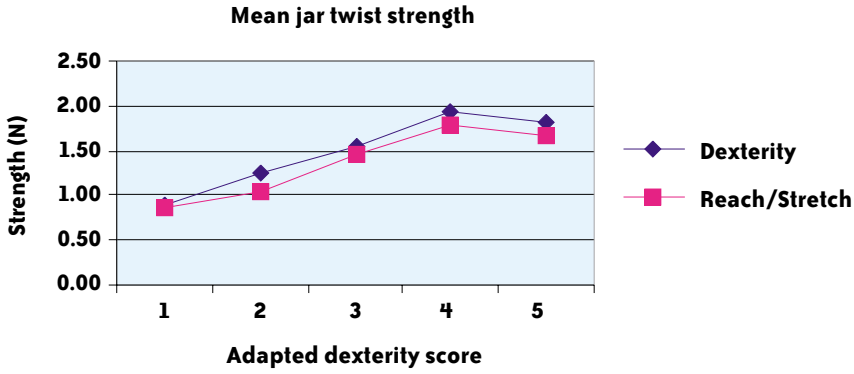
The original scaling for both 'dexterity' and 'reaching and stretching' included eleven and ten severity categories respectively. In order to increase the sample size at each level of severity, and secondly to eradicate any errors in rating individuals either by the interviewer or due to inherent problems with the OPCS scale itself, both of these scales were reduced to five point scales. These are shown below:

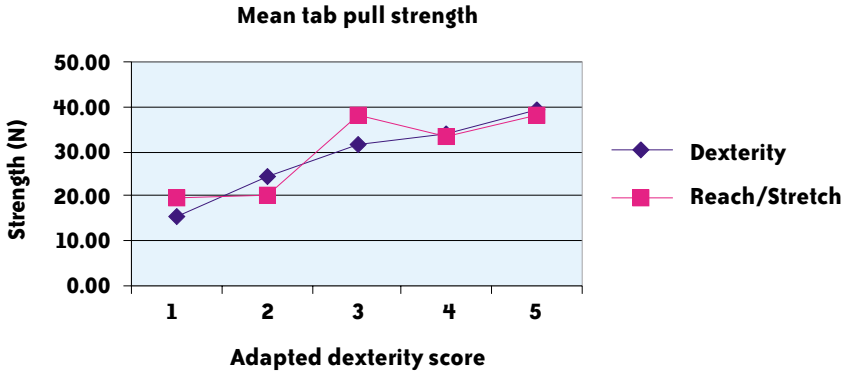
OPCS severity category		Adapted severity score
Dexterity	**Reaching and stretching**	
10.5	9.5	1
9.5	9	
8	8	2
7	7	
6.5	6.5	3
5.5	5.5	
4	4.5	4
3	3.5	
2	2.5	5
1	1	
0.5		

The adapted classification was used to produce graphs using the results from the trials to give mean strengths for the samples used at each level of severity and for each task. The resulting graphs are shown below.

The graphs show a good relationship between strength and severity for both 'Dexterity' and 'Reaching and Stretching'. In all cases however, the line for 'Dexterity' revealed a more linear relationship. Additionally, since the sample size for 'Dexterity' (n = approx. 300) was significantly larger than for 'Reaching and Stretching' (n = approx. 230) it was decided to use 'dexterity' for further data analysis including t-tests and the population estimates referred to earlier.


Mean ring pull strength
80.00
60.00
40.00
20.00
0.00
Strength (N)
1
2
3
4
5
Adapted dexterity score
Dexterity
Reach/Stretch


Mean jar twist strength
2.50
2.00
1.50
1.00
0.50
0.00
Strength (N)
1
2
3
4
5
Adapted dexterity score
Dexterity
Reach/Stretch


Mean tab pull strength
50.00
40.00
30.00
20.00
10.00
0.00
Strength (N)
1
2
3
4
5
Adapted dexterity score
Dexterity
Reach/Stretch

Appendix 2
Statistical treatment of results

DEFINITIONS OF TERMS USED

The purpose of statistical treatment of the results is to enable decisions to be made concerning whether the differences between to comparable entities represent a genuine effect or just a chance fluctuation. The T-test as it is known, is such a test and that gives a probability value along these lines. The P value states the probability that the results occurred as a result of chance. The convention used is to state the significance in terms of a P value for example, is $P \leq .05$ ie the probability of something occurring by chance is less than or equal to one in 20. The lower the P value the less the possibility of the effect occurring as a result of chance.

1.0 TWO HANDED GRIP AND TWISTING STRENGTH (AS WHEN UNSCREWING A JAR LID)

Table 1 Differences between impairment categories (t-test)

Dexterity Score	1	2	3	4	5
1			0	X	X
2			X (not S85, K65, K85	X	X (not S85, K65)
3				X (not S45, S65, K45	0
4				0	
5					

S45, S65, S85 = smooth lids of 45, 65 and 85 mm diameter
K45, K65, K85 = knurled lids of 45, 65 and 85 mm diameter
X = significant difference at 0.05 level
0 = not significant

Table 2 Correlation between measurements (Pearson correlation)

	Smooth lid diameter			Knurled lid diameter		
	S45mm	S65mm	S85mm	K45mm	K65mm	K85mm
S45mm	1.000	0.567	0.667	0.684	0.671	0.628
S65mm		1.000	0.713	0.635	0.796	0.690
S85mm			1.000	0.769	0.883	0.900
K45mm				1.000	0.810	0.767
K65mm					1.000	0.908
K85mm						1.000

2.0 FINGER GRASP AND PULL STRENGTH

Table 3 Tabs (lateral pull only) - Differences between impairment categories (t-test)					
Dexterity Score	**1**	**2**	**3**	**4**	**5**
1		X (Not 6mm)	X	X	X
2			X (Not 40mm)	X (Not 10mm, 40mm)	X
3				O	X (Not 6mm,10mm)
4					X (Not 6mm, 10mm)
5					

X = significant difference at 0.05 level

0 = not significant

Table 4 Blocks - Differences between impairment categories (t-test)					
Dexterity Score	**1**	**2**	**3**	**4**	**5**
1		X	X	X	X
2			X	X	X
3				X	X
4					X
5					

X = significant difference at 0.05 level

0 = not significant

Table 5 Tabs - Correlation between measurements (Pearson correlation)			
	Tab widths		
	6mm	**10mm**	**40mm**
6mm tab	1.000	0.951	0.768
10mm tab		1.000	0.815
40mm tab			1.000

Table 6 Blocks - Correlation between measurements (Pearson correlation)		
	Block thickness	
	20mm	40mm
20mm	1.000	0.943
40mm		1.000

3.0 RING PULL STRENGTH

Table 7 Differences between impairment categories (t-test)					
Dexterity Score	1	2	3	4	5
1		X (not30mm)	X	X	X
2			X	X	X
3				0	X
4					X (not 20mm, 30mm)
5					

X = significant difference at 0.05 level

0 = not significant

Table 8 Correlation between measurements (Pearson correlation)			
	Ring pull diameter		
	17mm	20mm	30mm
17mm	1.000	0.855	0.778
20mm		1.000	0.892
30mm			1.000