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Introduction and background

This report summarises the results of the second phase of a research study funded by the Consumer and Competition Policy Directorate of the Department of Trade and Industry (DTI) to provide designers with ergonomics data for use in the design of safer products.

The University of Nottingham has worked with DTI to produce a series of publications containing ergonomics data. The three publications on children, adults and older adults ('Childata', 'Adultdata' and 'Older Adultdata') contain the most up-to-date anthropometric and physical strength data for countries around the world. However, their production highlighted important 'gaps' in the data available for direct use in product design.

This report describes the second phase of the two stage research program which was undertaken to try to address some of these data 'gaps'. In the first phase, potential needs for design-applicable data were identified and prioritised and new strength data were collected to meet some of those needs. Data were collected on the following strength measurements:

- Finger push strength
- Pinch-pull strength
- Hand grip strength
- Wrist twisting strength
- Push and pull strength.

These data are available in a previous report from the DTI:

Strength Data for Design Safety – Phase 1. DTI, October 2000, URN 00/1070.

Which is available from

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Consumer and Competition Policy Directorate
1 Victoria Street, London SW1H 0ET
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Internet: www.dti.gov.uk
or Product Safety and Testing Group
School of Mechanical, Materials, Manufacturing, Engineering and Management
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This current report presents data from a second series of strength measurements. The report consists of three main sections:

1. Data collection methodology
2. Data sheets
3. Appendices

In Section 1 of the report, the research methodology is described. In Section 2, detailed descriptions of the measurements and the results are presented in the form of 'data sheets', and in Section 3, the statistical analyses performed are presented as appendices. The data sheets are repeated on pull out pages at the back of the report, for easy reference.

The data sheets, detailed in section 2, show the new data for all age groups. For easier reference these data have been colour coded by age to fit in with the age ranges in CHILDATA, ADULTDATA and OLDER ADULTDATA. The colours used to highlight each age range is that used for the background colour on the cover of each publication. For example CHILDATA is white (□), ADULTDATA is grey (■) and OLDER ADULTDATA is pink (■).

Section 1

Data Collection Methodology

In this second phase of research, data have been collected on a total of 8 strength measurements.

These are:

1. Push and pull strength
2. Push with the thumb or 2 or more fingers
3. Push with the shoulder (at 90% and 100% of shoulder height)
4. Pull with different grips
5. Wrist twisting and push-and-turn strength
6. Pull on a can ring-pull
7. Press and lift with the foot
8. Pull on 20mm knob

Subjects

To provide designers with a comparable set of design-applicable data for all age groups, children through to older adults were measured in the study. Around 150 subjects from the UK aged from 2 to 90 years have been measured for each strength measurement. Subjects were grouped into 5 or 10 year age bands, with around 15 individuals in each band, although this varied slightly between each measurement. Subject numbers are described separately for each force measurement in the data sheets (Section 2). The anthropometric details of the subjects are described in the corresponding appendices. Subjects were not selected to be representative of socio-economic criteria.

Measurements

Measurements were taken for a total of eight different force exertions, and are summarised below. Detailed descriptions of each measurement can be found in Section 2.

- *push and pull strength* - maximum static strength when pushing and pulling on a cylindrical bar, whilst standing, and using both one (dominant) hand and two hands. The bar was placed at shoulder height, and positioned both vertically and horizontally.
- *push with the thumb or 2 or more fingers* - maximum static pushing strength on a button using either the thumb or two or more fingers, whilst either standing or seated. The button was positioned at elbow height whilst standing, and at seat pan height whilst seated (small children allowed to rest feet on box). Forward pushing strength was measured with the fingers and downwards strength with the thumb and with the fingers.
- *push with the shoulder (at 90% and 100% of shoulder height)* - maximum static pushing force with the shoulder pushing on a force plate whilst standing. The force plate was positioned at 90% and 100% of the shoulder height.
- *pull with different grips* - maximum static pulling force on two different handle types (an under-hand grip handle and a round handle), whilst standing, and using both one (dominant) hand and two hands. The handle was positioned at elbow height.
- *wrist twisting and push and turn strength* - maximum static torque (clock-wise) on two different handle types, whilst standing, and using one (dominant) hand. Two knobs were used: a circular knob

(20mm diameter) and a push-and-turn knob (40mm). The push-and-turn knob had two push resistances, 10 Newtons and 20 Newtons. Both knobs were positioned at elbow height, vertically and horizontally.

- *pull on a can ring-pull* - maximum static pull strength when opening a can ring-pull, whilst standing. The can was held with one hand and pull force exerted with the other. The cans were freely moveable and subjects were free to adopt their own posture. Pull strength was measured with the ring-pull in the starting position (flat to the top of the can) and at an angle of 75° to the top of the can.
- *press and lift with the foot* - maximum static strength when pressing and lifting with the foot on a bar and a pedal, whilst standing, and using one (dominant) foot. The pedal and bar were positioned at instep height.
- *pull on 20mm knob* - maximum static pulling strength on a small round knob, whilst standing, and using both one (dominant) hand and two hands. The handle was positioned at elbow height.

Procedure

Subjects were asked to exert their maximum strength at all times, described as the highest force he or she could exert without causing injury. Subjects were instructed to build up to their maximum strength in the first few seconds, and to maintain maximum strength for a further few seconds. Where only one-handed strength was measured, subjects were instructed to use their dominant hand. Subjects performed two repetitions (lasting five seconds) for each experimental condition, and were given a two-minute rest interval between each exertion. If standing during testing subjects were free to adopt their own posture. The testing devices were adjusted and positioned at various heights according to which test was being performed, however the positions were always specified according to each subject's anthropometric measurements, such as shoulder height or instep height. Subjects were encouraged to exert maximal effort during testing and were able to obtain visual feedback from the testing device.

Equipment

Pull on 20mm knob, push with thumb or two or more fingers and wrist-twisting/push and turn strength (with torque attachment) were measured on a series of specially made handles which were attached to a Mecmesin™ Advanced Force Gauge (AFG 500N). Push and pull strength, pull with different grips and push with shoulder at 90% and 100% of shoulder height were measured with strain gauges attached to custom-made equipment. Press and lift with foot strength was measured by attaching a bar and pedal to a Kistler Type 9281B11 force plate fitted into the floor. Pull force on the can ring-pulls was measured using specially designed cans containing strain gauges.

Results

The results for each of the measurements are presented in turn as separate 'data sheets'. Each measurement is defined, and the method of measurement, number of subjects measured, and the data

collected are detailed. Data are presented separately for males and females and are also shown graphically. Differences in strength due to age and sex, as well as differences between experimental conditions, were analysed by means of a t-test, and these findings are presented in Appendices 1- 8. A correlation coefficient matrix detailing the relationship between all measurements can also be found in Appendix 9.

Effect of sex

For most measurements, no significant differences in maximum strength were found between male and female children (2-15 years). With some exceptions, in adults aged 16 years and over, males were generally found to be significantly stronger than females. Notable exceptions were: pushing with the shoulder at 90% of shoulder height and pulling on a very small handle (a 20mm diameter knob).

Effect of age

Generally, strength was seen to increase with age throughout childhood, to peak in adulthood, and then to decrease with age from around 50 years. There were generally significant differences between each successive age group.

Using the data

When using the data in this study, there are several factors which must be considered:

- Little correlation was found between the eight measurements, suggesting that the forces exerted were action-specific. That is, the size, shape and orientation of the handle or control, the directions of force and the number of hands used all affected the amount of force that could be exerted. However, some relationships were found: pushing force on a bar correlated significantly (across all conditions) with pushing forwards or downwards with the thumb or four fingers and with pushing with the shoulder (at 100% of shoulder height). Also wrist twisting strength (on a round knob and on a push and turn knob) correlated significantly with pulling strength on a can ring-pull.
- Within each measurement, significant differences were found between the experimental conditions. Biomechanical factors such as posture and the direction of movement affected strength. For instance, in all cases where measurements were made with one and two hands, the forces exerted with two hands were significantly higher than with one hand. Pushing on a bar generated significantly higher forces than pulling, as did pushing with the shoulder at 90% of shoulder height compared to pushing at 100%. Pressing down with the foot was significantly higher than lifting with the foot, and pushing down with the fingers was significantly higher than pushing down with just the thumb. The size, design and orientation of the handle or control also affected strength. Pulling on a round (55mm) handle generated significantly higher forces than pulling with an under-hand grip; wrist twisting strength on a push and turn knob with a push resistance of 10 Newtons was significantly higher than a knob with a push resistance of 20 Newtons. Pulling strength on a vertical can ring-pull was significantly higher than when the ring-pull was flat to the top of the can.
- No restrictions were placed on posture and subjects were able to grip and manipulate the various handles and knobs as they chose. The amount of force that can be exerted in such a free posture is known to be greater than that generated in a standardised posture (where subjects are often instructed to stand upright with their elbows flexed to 90 degrees).
- Subjects were instructed to exert their maximum strength (the highest force he or she could exert without causing injury).

Section 2

Data Sheets

1 Push and pull strength

Description

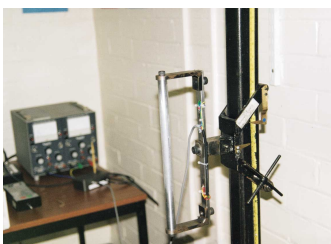
Maximum static strength when pushing and pulling with one and two hands on a cylindrical bar placed at shoulder height, in Newtons (N).

Method

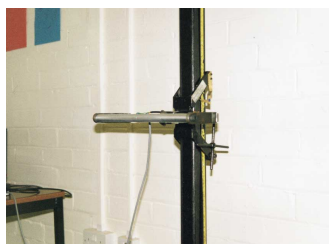
The subject stands in front of the measuring device and adopts a free posture. A static pushing or pulling force is exerted on a cylindrical bar placed at shoulder height (ie the bar doesn't move), with the dominant hand then with both hands. Subjects are stood behind a line on the floor, level with the bar. Subjects are instructed to build up their maximum strength in the first few seconds and to maintain maximum strength for a further few seconds.

Handle type and size

A cylindrical bar (20mm round and 300mm long), oriented vertically and horizontally, with the middle of the bar positioned at shoulder height.



Vertical bar for push/pull



Horizontal bar for push/pull



Pulling with two hands



Pushing with one hand

Subject numbers

154 subjects were measured:

Age (Years)	Male	Female	Total
2-5	7	8	15
6-10	4	8	12
11-15	7	6	13
16-20	18	5	23
21-30	6	8	14
31-50	9	9	18
51-60	4	5	9
61-70	5	14	19
71-80	9	13	22
81-90	2	7	9
Total	71	83	154

Anthropometric variables (stature, weight, elbow height, hand length and hand breadth) for all subjects can be found in Appendix 1a.

Analysis

Effect of sex

For all pushing and pulling actions, no significant difference was found between males and females aged between 2 and 30, with the exception of pushing with one hand in a vertical position in the 11 to 15 age group, where females exerted significantly higher forces. Males were found to exert significantly higher forces than females between ages 31 and 50 and 61 and 70 for all pulling conditions, and for pushing with two hands horizontally (ages 31-50 only) and vertically (ages 61-70 only) (Appendix 1b).

Effect of age

Mean maximum push and pull strength in males increases generally up to aged 50 and then decreases gradually to 90 years. This same general pattern was found for females, strength increasing up to 50 years then decreasing, however mean maximum strength appears to dip between the ages of 6 and 10 years and 20 to 30 years. However few significant differences were found between the age groups (Appendix 1c).

Effect of number of hands, orientation of the bar and pushing versus pulling

A significant difference in strength was found between both the number of hands used, and the orientation of bar, for both males and females. As expected, two hands exerted higher forces than one hand. Pushing was found to yield higher forces than pulling for both males and females in both orientations. Pushing with the handle in the vertical orientation with one hand yielded significantly higher forces than the horizontal orientation (Appendix 1d). Correlation coefficients for all measurements can be found in Appendix 1e.

Results

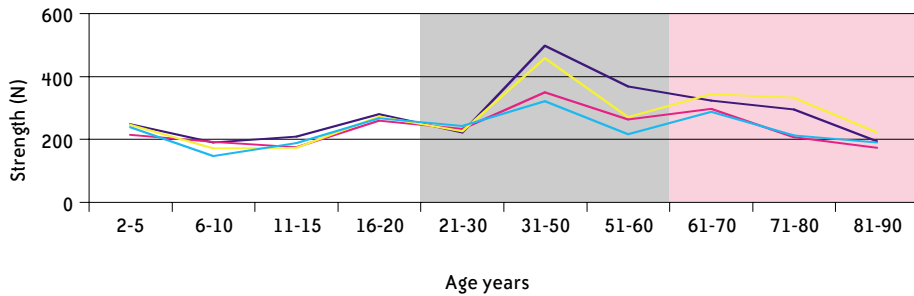
Push and pull on a cylindrical bar - one handed strength

Age (years)	Sex	Orientation	Push (N)				Pull (N)			
			No.	Mean	SD	Range	No.	Mean	SD	Range
2 – 5	m	Vertical	7	246.28	68.33	147.30 - 334.68	7	237.27	72.87	163.56 - 356.02
		Horizontal		246.90	82.89	129.87 - 360.82		214.46	66.48	106.24 - 310.97
	f	Vertical	8	245.89	152.80	51.44 - 456.69	8	223.96	147.41	44.82 - 442.01
		Horizontal		259.51	167.29	47.08 - 456.69		227.54	131.67	32.53 - 384.68
6 – 10	m	Vertical	4	170.18	99.45	86.30 - 304.17	4	146.16	84.14	69.39 - 261.84
		Horizontal		188.70	141.71	60.15 - 378.25		191.20	144.78	48.91 - 380.58
	f	Vertical	9	187.49	107.90	86.30 - 452.33	9	147.64	63.45	77.58 - 294.60
		Horizontal		177.81	124.78	81.94 - 500.26		150.83	84.97	57.10 - 364.21
11 – 15	m	Vertical	6	172.72	87.17	47.08 - 286.74	6	186.77	88.72	36.63 - 302.79
		Horizontal		207.58	117.10	47.08 - 400.04		175.17	70.61	44.82 - 253.65
	f	Vertical	6	312.89	125.14	169.09 - 500.26	6	260.47	83.66	143.09 - 372.40
		Horizontal		292.55	126.76	173.45 - 522.05		222.26	56.12	147.19 - 310.97
16 – 20	m	Vertical	14	271.80	117.33	164.73 - 565.62	14	267.10	116.97	130.81 - 499.33
		Horizontal		279.90	110.30	138.59 - 504.62		258.33	96.94	167.66 - 487.05
	f	Vertical	5	349.49	159.20	134.23 - 504.62	5	229.90	96.87	106.24 - 323.26
		Horizontal		340.78	174.21	112.44 - 508.98		238.91	92.23	110.33 - 315.07
21 - 30	m	Vertical	6	225.01	90.08	73.23 - 317.25	6	242.05	127.25	81.67 - 421.53
		Horizontal		221.38	99.02	77.58 - 339.03		231.81	107.92	110.33 - 384.68
	f	Vertical	8	231.73	183.49	60.15 - 609.20	8	224.99	154.07	102.14 - 548.47
		Horizontal		223.56	183.01	55.80 - 569.98		212.19	135.34	65.29 - 429.72
31 – 50	m	Vertical	10	457.12	171.77	190.88 - 722.49	10	320.39	90.15	196.32 - 495.24
		Horizontal		497.21	193.85	195.24 - 879.36		347.83	96.22	212.70 - 495.24
	f	Vertical	9	315.31	111.16	147.30 - 482.83	9	225.90	41.44	163.56 - 282.31
		Horizontal		328.38	137.59	129.87 - 574.34		233.17	51.06	147.19 - 298.69
51 – 60	m	Vertical	4	270.40	53.77	208.31 - 339.03	4	215.77	33.50	184.04 - 261.84
		Horizontal		367.36	71.29	278.03 - 443.61		261.84	26.54	233.17 - 286.41
	f	Vertical	5	315.50	101.38	208.31 - 426.18	5	229.08	89.24	134.90 - 323.26
		Horizontal		272.80	97.99	177.81 - 391.32		226.62	51.27	163.56 - 278.22
61 – 70	m	Vertical	5	342.52	207.99	64.51 - 648.42	5	286.41	152.03	40.72 - 442.01
		Horizontal		322.48	198.36	51.44 - 609.20		295.41	164.56	44.82 - 507.52
	f	Vertical	14	206.75	135.78	55.80 - 508.98	14	153.04	95.27	40.72 - 384.68
		Horizontal		190.88	111.29	51.44 - 426.18		152.74	83.62	57.10 - 327.35
71 – 80	m	Vertical	8	331.02	128.42	124.90 - 539.49	9	211.20	124.63	26.77 - 346.14
		Horizontal		293.92	119.33	63.66 - 459.40		206.53	111.89	22.57 - 320.93
	f	Vertical	13	247.42	150.88	116.80 - 680.82	13	239.28	113.60	106.24 - 472.21
		Horizontal		261.21	132.91	116.80 - 577.18		244.96	108.77	134.90 - 514.23
81 – 90	m	Vertical	2	221.48	69.96	172.01 - 270.95	2	188.56	74.29	136.03 - 241.08
		Horizontal		193.21	16.66	181.44 - 204.99		171.75	38.63	144.43 - 199.06
	f	Vertical	7	258.16	164.64	101.35 - 534.78	7	225.48	154.15	47.78 - 472.21
		Horizontal		245.37	143.18	82.50 - 506.51		223.07	137.45	51.98 - 455.40

Push and pull on a cylindrical bar - two handed strength

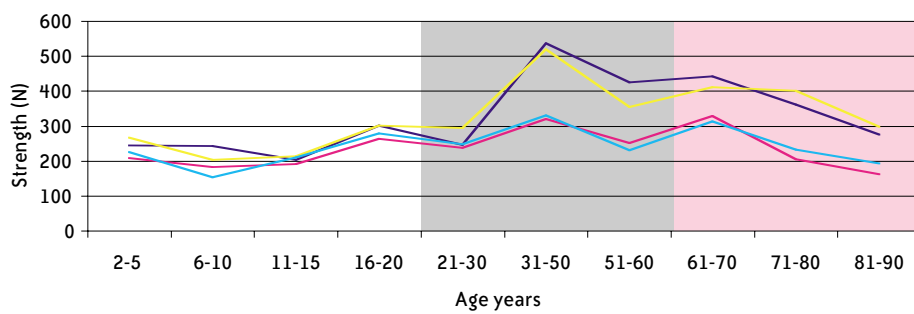
Age (years)	Sex	Orientation	Push (N)				Pull (N)			
			No.	Mean	SD	Range	No.	Mean	SD	Range
2 – 5	m	Vertical	7	266.20	59.78	164.73 - 334.68	7	225.59	75.74	126.70 - 323.30
		Horizontal		244.41	78.67	147.30 - 373.89		208.01	63.02	110.30 - 294.60
	f	Vertical	8	296.00	210.41	42.72 - 604.84	8	258.76	171.06	44.80 - 491.10
		Horizontal		280.21	182.76	60.15 - 539.48		248.00	188.54	28.40 - 560.80
6 – 10	m	Vertical	4	202.86	149.79	77.58 - 413.11	4	152.30	82.38	57.10 - 253.60
		Horizontal		243.17	176.93	99.37 - 495.90		183.03	111.42	61.20 - 306.90
	f	Vertical	9	214.60	141.70	108.09 - 574.34	9	164.01	63.55	69.40 - 270.00
		Horizontal		137.14	25.96	99.37 - 190.88		146.27	66.12	57.10 - 294.60
11 – 15	m	Vertical	6	212.67	138.32	47.08 - 461.04	6	209.28	129.86	48.90 - 442.00
		Horizontal		203.23	103.13	68.87 - 386.97		190.85	104.45	48.90 - 372.40
	f	Vertical	6	376.80	137.35	195.24 - 565.62	6	278.90	91.90	151.30 - 417.40
		Horizontal		318.70	122.62	190.88 - 522.05		232.50	61.04	134.90 - 323.30
16 – 20	m	Vertical	14	301.68	108.62	177.81 - 600.48	14	278.51	122.30	130.80 - 597.60
		Horizontal		301.37	130.42	138.59 - 626.63		263.61	115.15	139.00 - 585.30
	f	Vertical	5	389.58	160.95	151.66 - 530.76	5	229.06	94.81	102.10 - 347.80
		Horizontal		372.15	184.48	142.95 - 583.05		216.78	75.30	102.10 - 290.50
21 – 30	m	Vertical	6	294.73	125.61	86.30 - 421.83	6	248.18	113.30	106.20 - 384.70
		Horizontal		245.35	109.22	90.66 - 356.46		237.27	99.78	122.60 - 356.00
	f	Vertical	8	256.24	209.03	55.80 - 644.06	8	237.78	179.79	102.10 - 618.10
		Horizontal		230.64	205.09	55.80 - 644.06		206.56	122.38	94.00 - 454.30
31 – 50	m	Vertical	10	518.56	185.49	221.38 - 805.29	10	329.41	96.64	171.80 - 499.30
		Horizontal		536.86	216.83	212.67 - 905.51		320.39	91.70	188.10 - 450.20
	f	Vertical	9	353.56	125.42	164.73 - 556.91	9	219.99	54.30	139.00 - 298.70
		Horizontal		329.35	155.50	125.52 - 648.42		223.61	61.69	134.90 - 302.80
51- 60	m	Vertical	4	354.29	49.11	286.74 - 404.40	4	231.13	26.42	208.60 - 265.90
		Horizontal		425.09	74.32	347.75 - 526.41		251.60	24.66	225.00 - 278.20
	f	Vertical	5	391.32	140.96	199.59 - 530.76	5	258.58	113.32	159.50 - 425.60
		Horizontal		305.05	82.01	199.59 - 382.61		232.38	68.96	155.40 - 323.30
61 – 70	m	Vertical	5	410.50	242.55	86.30 - 766.07	5	313.42	166.97	53.00 - 499.30
		Horizontal		441.87	331.46	112.44 - 1001.37		328.16	190.24	40.70 - 568.90
	f	Vertical	14	226.05	128.61	77.58 - 513.33	14	154.21	93.53	57.10 - 331.40
		Horizontal		212.36	105.96	68.87 - 382.61		155.66	83.24	48.90 - 298.70
71 – 80	m	Vertical	8	399.92	185.21	115.48 - 737.36	9	232.20	140.05	35.20 - 434.40
		Horizontal		361.64	114.65	139.03 - 482.95		205.12	108.68	35.20 - 333.50
	f	Vertical	13	309.65	177.29	129.87 - 798.60	13	264.37	116.66	134.90 - 514.20
		Horizontal		313.84	185.10	138.59 - 826.87		264.36	122.89	122.60 - 518.40
81 – 90	m	Vertical	2	296.86	96.61	228.55 - 365.17	2	192.75	56.50	152.80 - 232.70
		Horizontal		275.66	6.66	270.95 - 280.37		161.25	59.47	119.20 - 203.30
	f	Vertical	7	336.91	225.53	106.06 - 756.20	7	214.09	114.83	77.20 - 396.60
		Horizontal		282.39	177.57	77.79 - 563.04		191.87	101.99	56.20 - 346.10

Mean maximum push and pull strength with one hand (males)



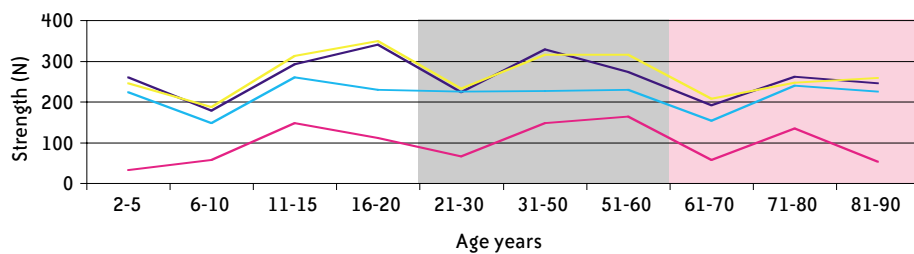
- Horizontal push with 1 hand
 - Horizontal pull with 1 hand
 - Vertical push with 1 hand
 - Vertical pull with 1 hand
- Childdata
 Adultdata
 Older adultdata

Mean maximum push and pull strength with two hands (males)



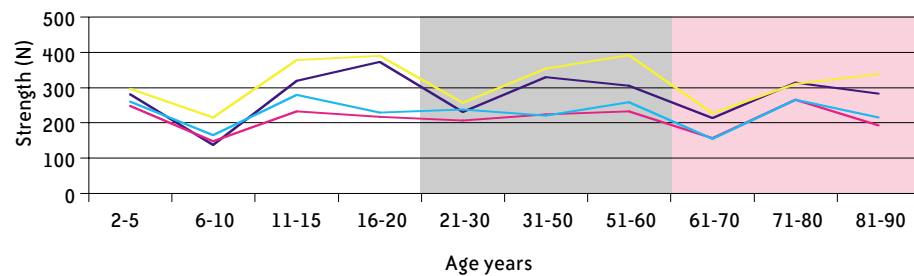
- Horizontal push 2 hands
 - Horizontal pull 2 hands
 - Vertical push 2 hands
 - Vertical pull 2 hands
- Childdata
 Adultdata
 Older adultdata

Mean maximum push and pull strength with one hand (females)



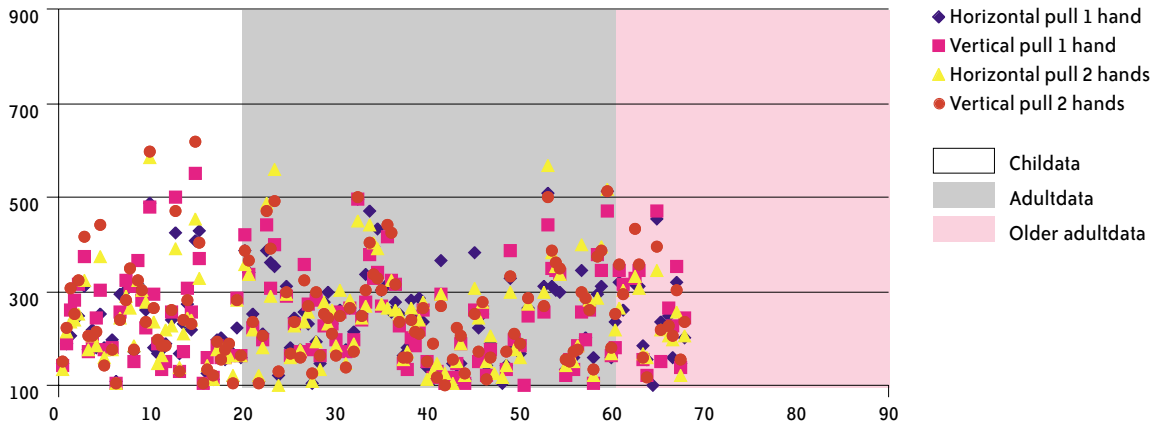
- Horizontal push 1 hand
 - Horizontal pull 1 hand
 - Vertical push 1 hand
 - Vertical pull 1 hand
- Childdata
 Adultdata
 Older adultdata

Mean maximum push and pull strength with two hands (females)

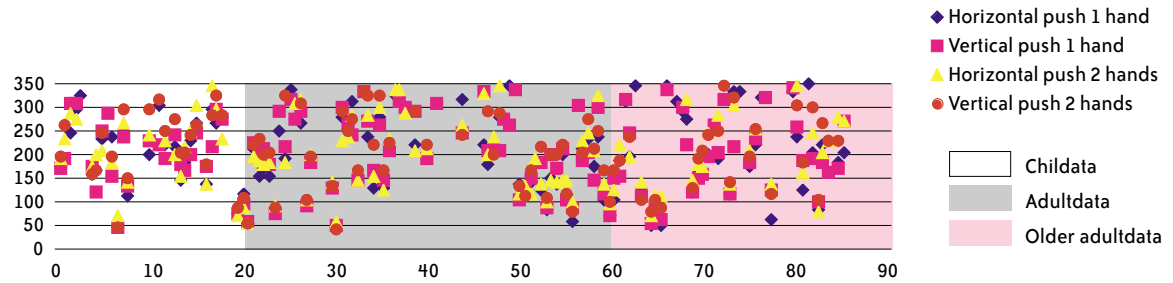


- Horizontal push 2 hands
 - Horizontal pull 2 hands
 - Vertical push 2 hands
 - Vertical pull 2 hands
- Childdata
 Adultdata
 Older adultdata

Maximum pull strength



Maximum push strength



2 Push with the thumb or 2 or more fingers

Description

Maximum static pushing strength using the thumb or two or more fingers, in Newtons (N).

Method

A static pushing force is exerted on a button using either the thumb or two or more fingers (subject can use as many fingers as they wish), using the dominant hand. The subject is either standing, with the button positioned at elbow height, or seated with the button positioned at the side of the hip, at seat pan height (430mm). Small children are allowed to rest their feet on a box. Subjects are instructed to build up their maximum strength in the first few seconds and to maintain maximum strength for a further few seconds. Three measurements were taken in each posture:

- 1) Pushing forward using finger pads only
- 2) Pushing down with thumb
- 3) Pushing down with finger pads

Button type and size

A plastic cube (50mm x 50mm).



Experimental trial: pushing down with the fingers at seat height



Experimental trial: pushing forward with the fingers at elbow height

Subject numbers

152 subjects were measured

Age (Years)	Male	Female	Total
2-5	8	8	16
6-10	5	8	13
11-15	7	5	12
16-20	14	5	19
21-30	7	9	16
31-50	7	8	15
51-60	4	5	9
61-70	4	15	19
71-80	9	14	23
81-90	2	8	10
Total	67	85	152

Anthropometric variables (stature, weight, elbow height, hand length and hand breadth) for all subjects can be found in Appendix 2a.

Analysis

Effect of sex

No significant difference was found from ages 2 to 15. However from ages 16 to 60 and 71 to 80 males exerted significantly higher force than females (Appendix 2b).

Effect of age

Pushing strength using two or more fingers or the thumb generally increases through childhood (2 to15), peaks in adulthood and decreases after 50 years for both males and females. A significant difference was found between nearly all age groups for all conditions (Appendix 2c).

Effect of pushing with the thumb or the fingers, and of orientation and position of the button

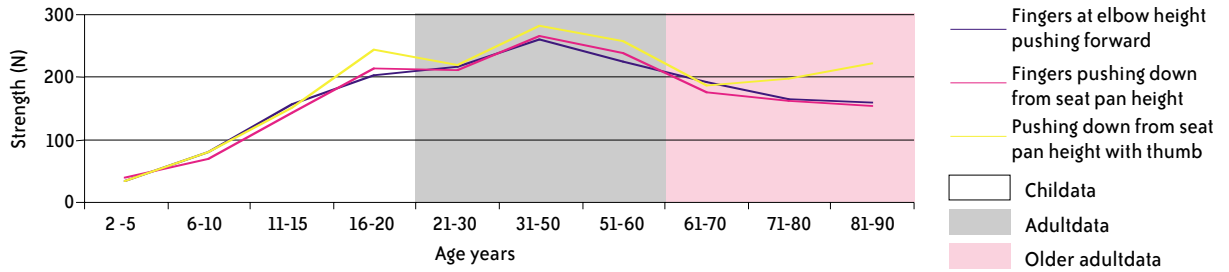
Pushing forward from the elbow with the fingers yielded significantly higher forces than pushing down from the hip with the fingers or with the thumb. Also, pushing down from the hip with the fingers yielded significantly higher forces than pushing down from the hip with the thumb (Appendix 2d). Correlation coefficients for all measurements can be found in Appendix 2e.

Results

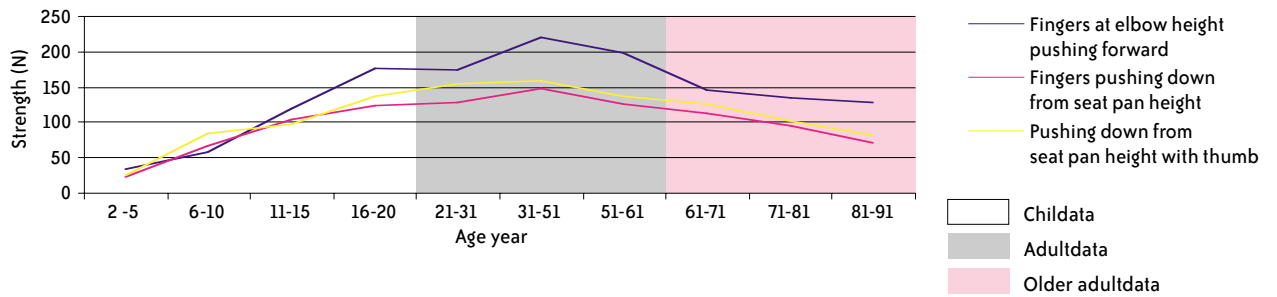
Pushing strength with the thumb or two or more fingers

		Pushing with two or more fingers (N)								Pushing with the thumb (N)			
		Pushing forward at elbow height				Pushing down at seat pan height				Pushing down at seat pan height			
Age (yrs)	Sex	No.	Mean	SD	Range	No.	Mean	SD	Range	No.	Mean	SD	Range
2 – 5	m	9	27.49	13.30	6.70 - 42.00	8	31.95	13.20	12.00 - 50.20	8	26.80	11.94	13.60 - 51.20
	f	8	20.80	9.93	6.10 - 34.70	8	22.26	9.61	9.00 - 37.50	8	24.16	8.30	10.30 - 36.30
6 – 10	m	5	65.86	24.06	36.10 - 91.30	5	56.18	20.78	33.70 - 82.30	5	66.62	31.28	36.10 - 104.10
	f	8	78.04	29.89	47.20 - 124.70	8	66.81	20.58	44.80 - 98.80	8	82.75	35.70	35.50 - 142.60
11 – 15	m	7	129.51	32.37	80.30 - 172.10	7	117.60	29.89	73.00 - 161.80	7	124.43	44.60	86.00 - 216.50
	f	5	96.10	12.53	84.00 - 114.10	5	103.20	13.42	91.80 - 126.30	5	97.24	17.20	78.50 - 123.20
16 – 20	m	14	168.39	34.89	98.80 - 234.30	14	176.40	39.19	102.60 - 230.00	14	202.36	56.17	96.00 - 307.40
	f	5	113.84	39.32	63.90 - 164.30	5	122.42	27.96	87.80 - 158.30	5	136.80	44.31	73.20 - 198.20
21 - 30	m	7	178.74	39.62	110.30 - 223.10	7	174.17	14.88	155.00 - 193.40	7	182.53	11.36	159.60 - 195.30
	f	9	139.27	24.36	103.80 - 179.30	9	128.03	26.04	101.30 - 161.60	9	153.03	29.15	122.50 - 209.00
31 – 50	m	7	216.04	45.24	167.40 - 285.40	7	219.61	40.57	161.70 - 281.60	7	233.40	52.36	179.00 - 311.70
	f	8	150.39	33.32	100.80 - 198.20	8	147.00	39.04	82.50 - 192.00	8	157.49	35.35	89.90 - 204.70
51 – 60	m	4	185.83	21.05	167.50 - 207.20	4	198.10	45.66	162.40 - 262.20	4	214.40	22.93	183.40 - 234.20
	f	5	124.48	27.26	92.60 - 162.10	5	125.96	34.69	107.30 - 187.80	5	136.46	44.67	77.80 - 181.60
61 – 70	m	4	158.65	55.03	80.70 - 209.20	4	145.30	44.43	87.10 - 192.80	4	155.63	45.79	90.30 - 187.60
	f	15	116.41	43.55	69.50 - 259.70	15	112.10	36.73	67.40 - 226.90	15	125.05	48.32	62.00 - 237.70
71 – 80	m	9	136.42	22.03	104.10 - 170.90	9	134.76	26.18	88.40 - 167.40	9	162.56	49.72	111.00 - 262.60
	f	14	90.49	27.25	49.10 - 144.40	14	93.35	27.03	41.50 - 133.90	14	101.50	32.05	53.70 - 154.20
81 – 90	m	2	131.15	59.18	89.30 - 173.00	2	126.35	45.47	94.20 - 158.50	2	185.00	90.51	121.00 - 249.00
	f	8	73.25	17.47	51.70 - 92.90	8	70.33	19.37	36.70 - 102.10	8	82.23	16.30	62.70 - 115.90

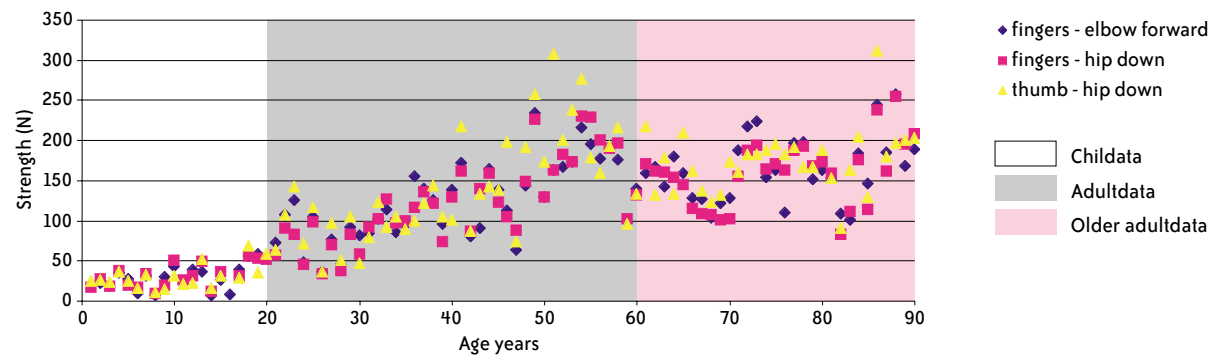
Mean maximum push strength with the thumb or 2 or more fingers (males)



Mean maximum push strength with the thumb or 2 or more fingers (females)



Maximum push strength when pushing with thumb or two or more fingers



3 Push with the shoulder

Description

Maximum static pushing force when pushing with the shoulder, at or near shoulder height and at 90% of shoulder height, in Newtons (N).

Method

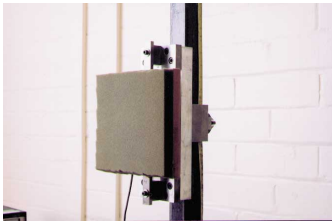
The subject stands in front of the measuring device and adopts a free posture. A static pushing force is exerted with the shoulder on a force plate. Subjects are stood behind a line on the floor, level with the bar. The force plate is positioned at shoulder at 90% and at 100% of the subject's shoulder height. Subjects are instructed to build up their maximum strength in the first few seconds and to maintain maximum strength for a further few seconds.

Pad type and size

A force plate (200mm x 200mm) covered with 25mm thick foam.

Button type and size

A plastic cube (50mm x 50mm).



Foam pad for measuring push with the shoulder



Measuring push with the shoulder at 90% of shoulder height

Subject numbers

152/140 subjects were tested

Push at 100% of shoulder height			
Age (Years)	Male	Female	Total
2-5	8	9	17
6-10	5	8	13
11-15	7	5	12
16-20	14	4	18
21-30	7	9	16
31-50	7	8	15
51-60	4	5	9
61-70	4	15	19
71-80	9	14	23
81-90	2	8	10
Total	67	85	152

Push at 90% of shoulder height			
Age (Years)	Male	Female	Total
2-5	9	8	17
6-10	5	8	13
11-15	7	5	12
16-20	7	5	12
21-30	7	6	13
31-50	9	8	17
51-60	4	4	8
61-70	5	14	19
71-80	9	13	22
81-90	2	5	7
Total	64	76	140

Anthropometric variables (stature, weight, elbow height, hand length and hand breadth) for all subjects can be found in Appendix 3a.

Analysis

Effect of sex

Males were significantly stronger than females when pushing at 100% of shoulder height from age 11 to 70, except at ages 31-50. When pushing at 90% of shoulder height, the only significant differences between the sexes were found in the 11 to 20 and 51 to 60 age groups (Appendix 3b).

Effect of age

As with the other measurements, strength generally increases in children, peaks in adulthood and declines in older adults. When pushing with the shoulder at both heights, those aged between 6 and 90 years were found to be significantly stronger than the 2 to 5 year olds. When pushing with the shoulder at 100% of shoulder height: 11 to 50 year olds were found to be significantly stronger than 2 to 10 year olds; 11 to 15 year olds were found to be significantly stronger than 71 to 90 year olds. 11-60 year olds were found to be significantly stronger than 71 to 90 year olds when pushing with the shoulder at 90% of shoulder height. (Appendix 3c).

Effect of the height at which people were pushing with the shoulder

Subjects were found to be able to yield a significantly higher mean strength when pushing with the shoulder at 90% of shoulder height when compared to pushing at 100% of shoulder height (Appendix 3d). Correlation coefficients for all measurements can be found in Appendix 3e.

Results

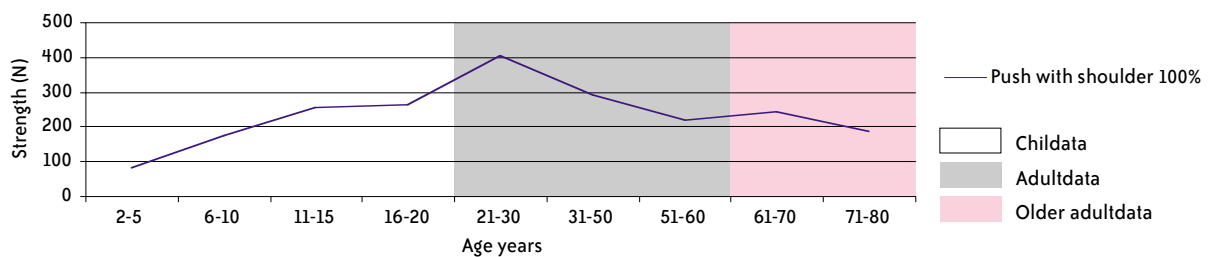
Pushing strength with the shoulder at 100% of shoulder height

100% of shoulder height (N)					
Age (years)	Sex	No.	Mean	SD	Range
2-5	m	8	79.78	35.02	51.58 -157.98
	f	9	72.39	12.85	47.33 - 94.14
6-10	m	5	172.45	48.11	98.40 -226.07
	f	8	130.85	42.68	64.35 - 196.28
11-15	m	7	255.25	35.30	213.30 - 298.42
	f	5	152.87	18.89	136.70 - 179.26
16-20	m	14	262.25	58.06	192.03 -413.33
	f	4	181.39	30.79	145.24 -209.05
21-30	m	7	401.77	86.51	238.84- 498.44
	f	9	201.48	37.09	136.70 -277.14
31-50	m	7	290.52	70.89	204.79 -392.05
	f	8	253.73	162.45	94.14 -630.37
51-60	m	4	216.50	33.76	187.77 -260.12
	f	5	152.02	17.70	132.44 - 175.00
61-70	m	4	242.03	44.96	204.79 -306.93
	f	15	169.33	58.92	89.89 - 349.49
71-80	m	9	186.82	63.33	102.65 -285.65
	f	14	136.40	63.29	60.10 -315.44
81-90	m	2	151.60	75.23	98.40 -204.79
	f	8	101.59	37.22	77.12 -187.77

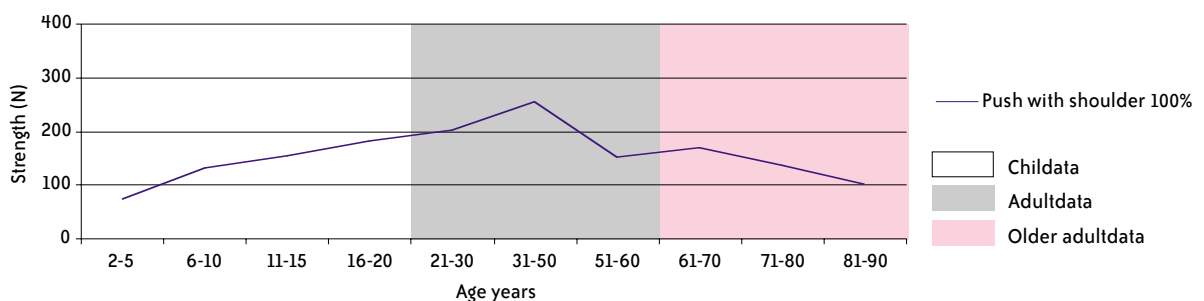
Pushing strength with the shoulder at 90% of shoulder height

90% of shoulder height (N)					
Age (years)	Sex	No.	Mean	SD	Range
2-5	m	9	105.96	46.56	51.58 - 179.26
	f	8	99.46	21.31	64.35 - 123.93
6-10	m	5	215.01	82.45	136.70 - 353.74
	f	8	237.24	119.62	106.91 - 460.14
11-15	m	7	432.78	76.12	349.49 - 528.23
	f	5	247.35	90.43	140.96 - 362.26
16-20	m	7	595.72	39.50	532.49 - 651.65
	f	5	312.04	111.68	217.56 - 455.88
21-30	m	7	620.04	100.35	511.21 - 749.53
	f	6	504.12	102.87	358.00 - 587.81
31-50	m	9	645.98	267.85	349.49 - 1102.76
	f	8	469.71	170.77	170.75 - 638.88
51-60	m	4	497.38	136.95	426.09 - 707.22
	f	4	281.40	39.47	226.07 - 319.70
61-70	m	5	510.36	157.04	387.79 - 783.58
	f	14	273.80	80.27	170.75 - 451.63
71-80	m	9	339.09	100.60	170.75 - 494.19
	f	13	228.36	70.27	102.65 - 336.72
81-90	m	2	281.40	18.06	268.63 - 294.16
	f	5	167.34	76.21	89.89 - 294.16

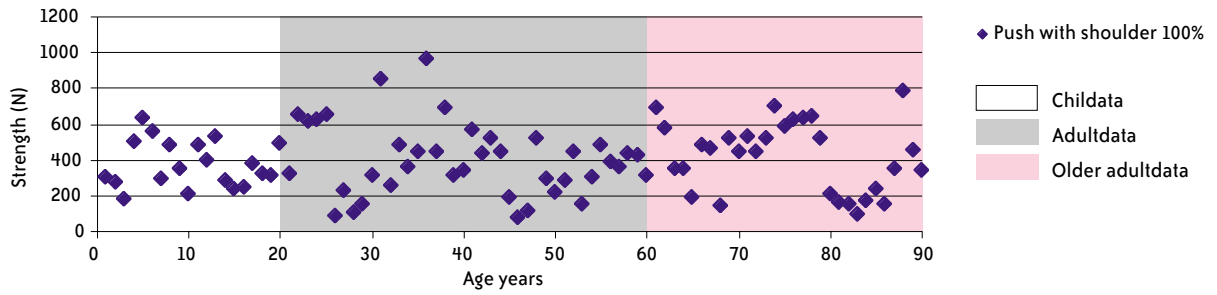
Mean maximum pushing strength with the shoulder at 100% of shoulder height (males)



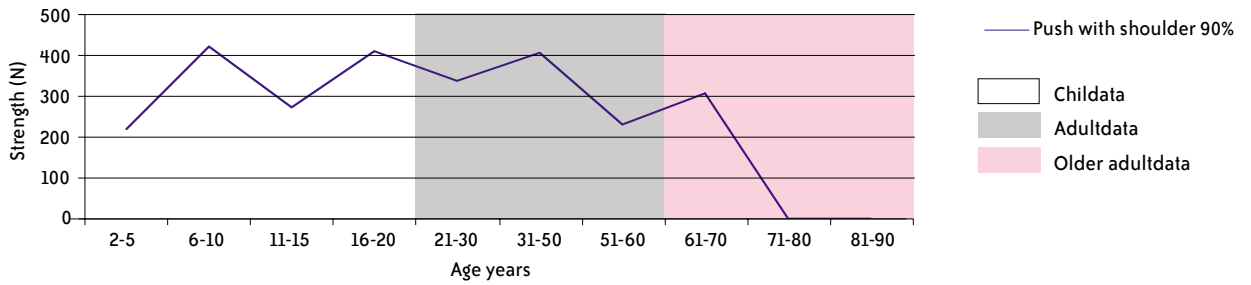
Mean maximum pushing strength with the shoulder at 100% of shoulder height (females)



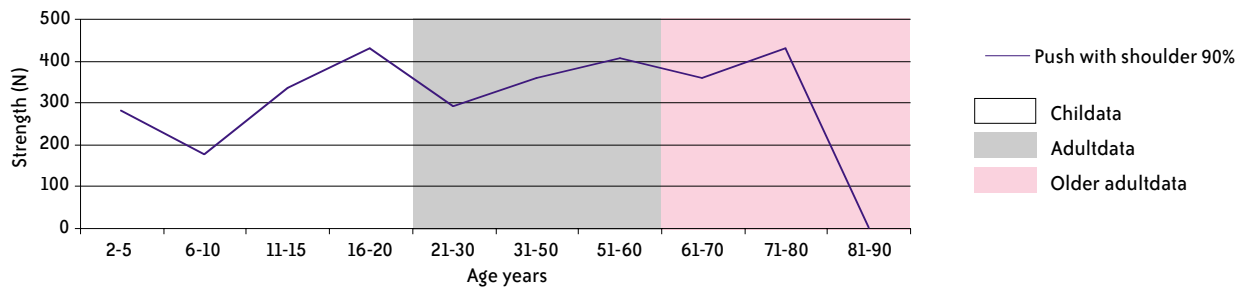
Maximum pushing strength with the shoulder at 100% of shoulder height



Mean maximum pushing strength with the shoulder at 90% of shoulder height (males)



Mean maximum strength for pushing with the shoulder at 90% of shoulder height (females)



Maximum pushing strength with the shoulder at 90% of shoulder height

