

4 Pull with different grips

Description

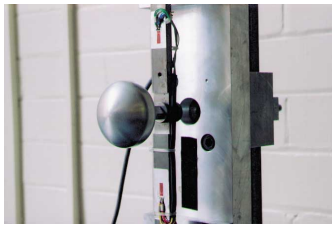
Maximum static pulling force on two different handle types, in Newtons (N).

Method

The subject stands in front of the measuring device and adopts a free posture. A maximum static pulling force is exerted on two different handle types (an under-hand grip handle and a round door knob). 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

Two handles positioned at elbow height: a round door knob (55mm diameter) and an under-hand grip handle (140mm long, 25mm/40mm high at the front/back, 20mm deep, 5mm thickness of metal).



55mm door knob



Pulling on 55mm knob



Underhand grip handle



Pulling with an underhand grip

Subject numbers

152 subjects were measured

Age (Years)	Male	Female	Total
2-5	6	3	9
6-10	5	8	13
11-15	7	5	12
16-20	14	5	19
21-30	6	9	15
31-50	7	8	15
51-60	4	4	8
61-70	4	15	19
71-80	8	14	22
81-90	2	8	10
Total	63	79	142

Anthropometric variables (stature, weight, elbow height, hand length and hand breadth) for all subjects can be found in Appendix 4a.

Analysis

Effect of sex

Males were found to be significantly stronger than females when using the under-hand grip handle with 1 hand, between the ages of 16-20, 31-60 and 71-80 years, and when using the round handle with 2 hands between the ages 21-50. Otherwise there were no significant differences (Appendix 4b).

Effect of age

Pulling with different grips generally increases with age throughout childhood, it peaks in adulthood and then decreases with age from around 50 years old. Some significant difference was found between the age groups (Appendix 4c).

Effect of the number of hands used and the handle type

Significant differences were found between the force exerted with the under-hand grip handle and the round handle, and between using one or two hands. The highest mean maximum forces were exerted with two hands. The forces exerted with the round handle were significantly higher than with the under-hand grip handle (Appendix 4d). Correlation coefficients for all measurements can be found in Appendix 4e.

Results

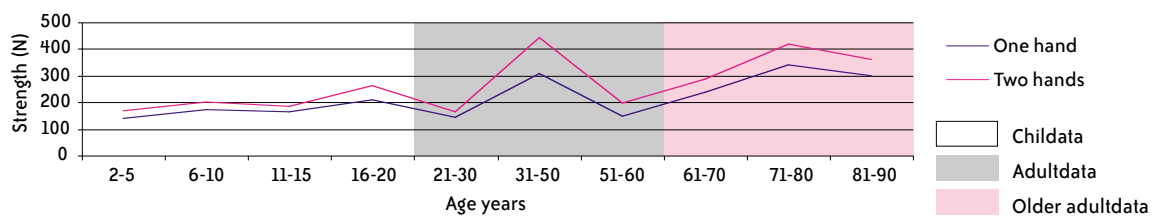
Pulling with different grips - one handed strength

		Underhand grip handle (N)				55mm round handle (N)			
Age (yrs)	Sex	No.	Mean	SD	Range	No.	Mean	SD	Range
2 – 5	m	6	9.75	8.90	0.44 - 24.19	6	140.91	42.08	65.13 - 184.54
	f	3	9.75	5.34	3.62 - 13.33	3	140.02	85.82	78.09 - 237.99
6 – 10	m	5	39.23	14.48	16.57 - 55.42	5	172.63	97.47	100.75 - 304.74
	f	8	48.80	26.50	24.19 - 101.40	8	205.02	57.51	110.46 - 273.62
11 – 15	m	7	109.42	60.23	10.09 - 202.35	7	163.63	54.69	87.80 - 267.68
	f	5	85.05	16.66	65.76 - 101.40	5	224.87	84.48	123.42 - 315.19
16 – 20	m	14	159.83	39.02	71.61 - 214.23	14	210.04	130.72	39.23 - 428.02
	f	5	101.49	35.44	42.47 - 137.03	5	175.99	72.53	94.28 - 291.43
21 - 30	m	6	153.32	42.55	103.99 - 214.23	6	142.09	99.17	19.81 - 285.50
	f	9	120.28	24.95	95.46 - 166.72	9	260.11	123.17	110.46 - 487.41
31 – 50	m	7	182.97	51.76	125.15 - 255.80	7	308.23	83.17	129.89 - 374.58
	f	8	123.16	24.89	87.80 - 160.78	8	208.12	94.55	65.76 - 338.94
51 – 60	m	4	145.94	21.95	125.15 - 172.66	4	145.94	21.95	125.15 - 172.66
	f	4	85.59	40.22	26.28 - 113.27	3	78.34	45.95	26.28 - 113.27
61 – 70	m	4	141.16	48.28	97.51 - 196.41	4	239.67	209.56	77.64 - 546.80
	f	15	121.14	74.45	48.95 - 243.92	15	329.48	170.15	59.82 - 606.19
71 - 80	m	8	112.53	38.81	59.82 - 160.78	8	341.91	269.82	30.13 - 624.00
	f	14	63.39	26.52	26.28 - 110.46	14	342.04	221.89	65.76 - 707.14
81 – 90	m	2	86.55	71.39	36.07 - 137.03	2	297.37	159.57	184.54 - 410.21
	f	8	50.01	20.04	23.04 - 77.64	8	210.93	121.57	24.19 - 379.21

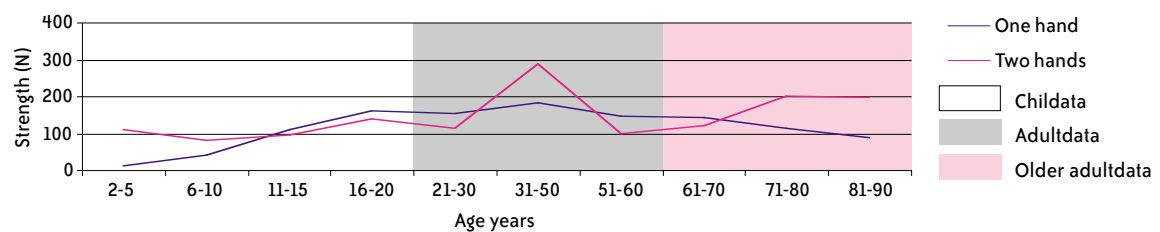
Pulling with different grips – two handed strength

Age (yrs)	Sex	Underhand grip handle (N)				55mm round handle (N)			
		No.	Mean	SD	Range	No.	Mean	SD	Range
2 – 5	m	6	109.52	60.99	45.71 - 226.11	6	169.70	46.39	94.28 - 237.99
	f	3	108.88	66.27	35.99 - 165.51	3	152.97	75.38	94.28 - 237.99
6 – 10	m	5	78.73	10.59	68.37 - 94.28	5	201.12	83.72	136.37 - 333.88
	f	8	139.16	41.02	68.37 - 184.54	8	265.01	87.18	136.37 - 368.64
11 – 15	m	7	93.08	54.41	35.99 - 196.41	7	183.83	96.97	97.51 - 392.39
	f	5	103.41	21.13	83.58 - 137.03	5	229.73	73.62	136.37 - 327.07
16 – 20	m	14	136.40	94.28	12.30 - 303.30	14	264.07	177.71	42.01 - 612.13
	f	5	95.40	38.74	36.00 - 137.00	5	186.78	76.53	100.75 - 303.31
21 - 30	m	6	111.78	93.30	3.62 - 232.05	6	161.97	104.09	26.28 - 315.19
	f	9	182.67	119.45	48.95 - 422.09	9	322.79	149.95	142.97 - 606.19
31 – 50	m	7	286.33	81.35	107.23 - 344.88	7	441.66	127.46	184.94 - 582.43
	f	8	137.20	72.32	30.13 - 273.62	8	270.54	170.30	83.58 - 594.31
51 – 60	m	4	98.40	125.84	12.30 - 285.50	4	197.87	201.47	42.00 - 493.35
	f	4	73.70	35.80	26.30 - 113.30	4	112.29	58.64	26.31 - 154.84
61 – 70	m	4	120.24	95.54	59.82 - 261.74	4	288.44	222.90	113.32 - 612.13
	f	15	186.49	126.02	29.52 - 457.72	15	405.50	193.24	172.04 - 760.59
71 - 80	m	8	200.13	169.11	18.25 - 416.15	8	416.94	303.22	59.76 - 748.72
	f	14	187.87	148.23	29.52 - 463.66	14	401.62	267.94	81.27 - 909.06
81 – 90	m	2	196.41	50.39	160.78 - 232.05	2	359.69	155.37	249.91 - 469.60
	f	8	107.09	72.83	0.44 - 208.29	7	274.43	104.86	160.78 - 433.96

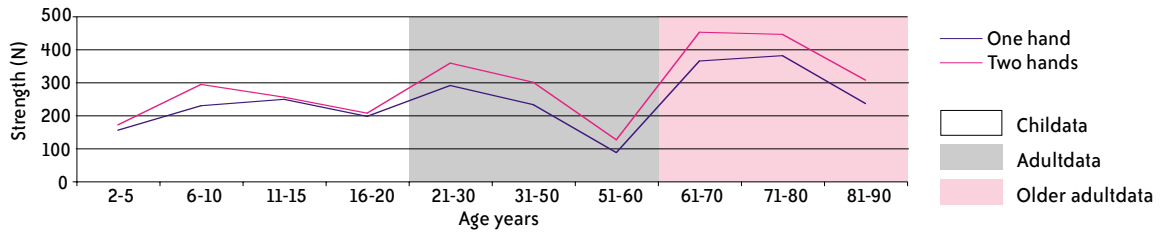
Mean maximum pulling strength on the round handle (males)



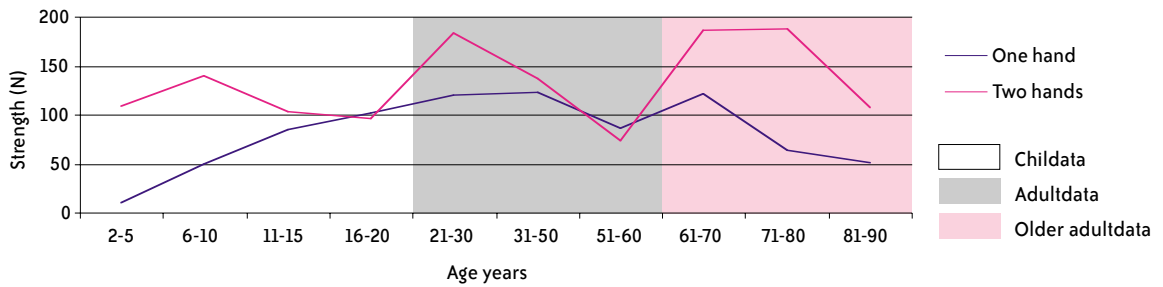
Mean maximum pulling strength on the under-hand grip handle (males)



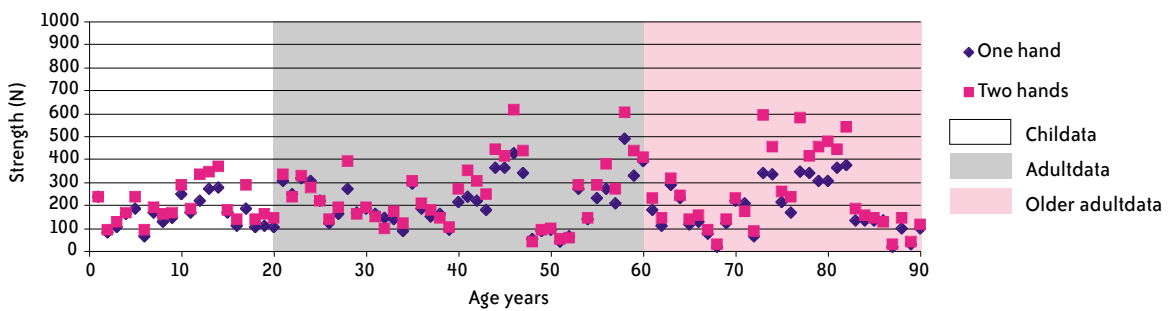
Mean maximum pulling strength on the round handle (females)



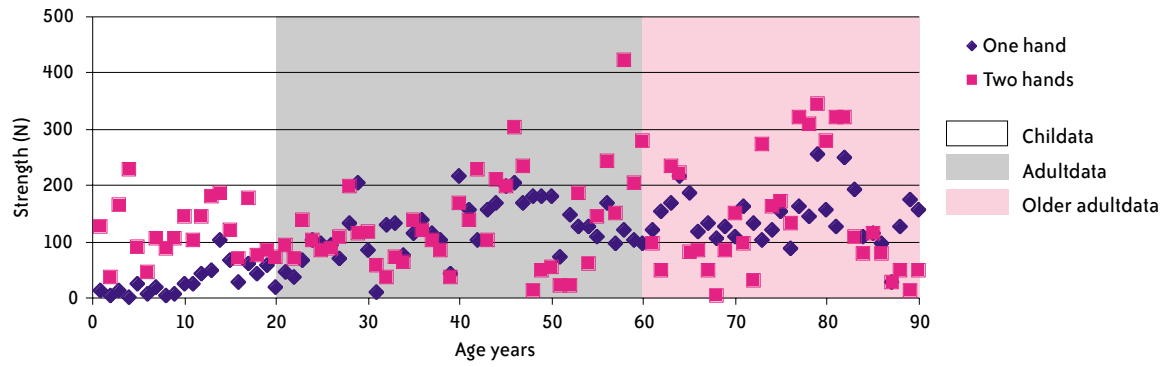
Mean maximum pulling strength on the under-hand grip handle (females)



Maximum pulling strength on the round handle



Maximum pulling strength on the under-hand grip handle



5 Wrist twisting and push-and-turn strength

Description

Maximum static torque (clock-wise) on two different handle types, in Newton-metres (Nm).

Method

The subject stands in front of the measuring device and adopts a free posture. A maximum static twisting force is exerted using one (dominant) hand on two types of handle: a circular knob and push and turn knob. 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

Three handles positioned vertically and horizontally:

- i) a round knob, 20mm diameter and 20 mm depth
- ii) a ridged push-and-turn knob of 40mm diameter with a ridge 15mm deep, 10mm wide, with a push resistance of 10 Newtons
- iii) as ii) with a push resistance of 20 Newtons.



Push and turn knob



Measuring twist force on the push and turn knob



20 mm knob



Measuring twist force on the 20 mm knob

Subject numbers

142 subjects were measured:

Age (Years)	Male	Female	Total
2-5	9	7	16
6-10	5	8	13
11-15	6	6	12
16-20	7	5	12
21-30	6	7	13
31-50	8	8	16
51-60	4	4	8
61-70	4	14	18
71-80	9	12	21
81-90	5	8	13
Total	63	79	142

Anthropometric variables (stature, weight, elbow height, hand length and hand breadth) for all subjects can be found in Appendix 5a.

Analysis

Effect of sex

Males were significantly stronger than females in wrist twisting strength using the push and turn knob across nearly all ages (16-80 years). When using the round knob, few significant differences between the sexes were found, the only exception being in the age groups 21-30 and 61-70 (vertical knob only) and 71-80 (horizontal knob only) (Appendix 5b).

Effect of age

Maximum strength for both vertical and horizontal wrist twisting increases generally throughout childhood (2-15 years), it peaks in adulthood, and then decreases with age from around 50 years. Some significant differences were found between the age groups but not consistently, except for ages 2-10 where all older age groups were significantly stronger (Appendix 5c).

Effect of handle type and orientation

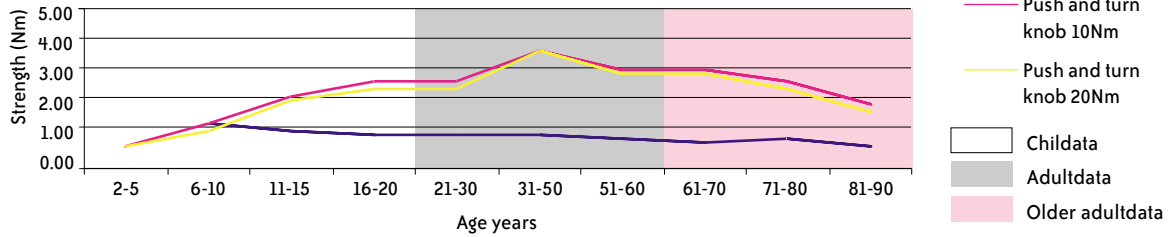
The handle type appears to significantly effect maximum strength, as significant differences were found between the circular knob and the ridged knob (10 & 20 Newtons) in both the horizontal and the vertical orientation. As expected, the push and turn knobs allowed a better grip and so generated higher forces than the circular knob, which had a smooth surface. Generally a significance difference was found between resistance of the two push-and-turn knobs (10 & 20N) with a higher force being generated on the knob with least resistance in both the horizontal and the vertical orientation (Appendix 5d). Correlation coefficients for all measurements can be found in Appendix 5e.

Results

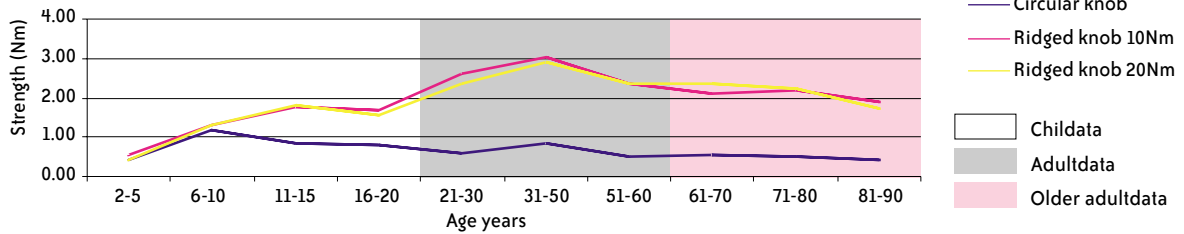
Wrist twisting strength

Age (yrs)	Sex	Orientation	Circular 20mm knob (Nm)				Push and turn knob - 10N resistance (Nm)				Push and turn knob - 20N resistance (Nm)			
			No.	Mean	SD	Range	No.	Mean	SD	Range	No.	Mean	SD	Range
2 - 5	m	Vertical	9	0.50	0.28	0.05 - 0.88	8	0.51	0.25	0.20 - 1.01	7	0.41	0.18	0.18 - 0.64
		Horizontal		0.51	0.37	0.04 - 1.29		0.54	0.25	0.25 - 0.93		0.54	0.27	0.23 - 0.88
	f	Vertical	7	0.60	0.28	0.60 - 1.00	7	0.44	0.21	0.18 - 0.74	7	0.40	0.26	0.16 - 0.89
		Horizontal		0.44	0.33	0.15 - 0.94		0.53	0.33	0.16 - 0.98		0.41	0.18	0.17 - 0.69
6 - 10	m	Vertical	5	1.06	0.43	0.56 - 1.75	5	1.04	0.54	0.36 - 1.71	5	0.96	0.53	0.48 - 1.58
		Horizontal		1.31	0.53	0.72 - 2.02		1.33	0.43	0.74 - 1.80		1.10	0.52	0.56 - 1.67
	f	Vertical	8	1.12	0.30	0.61 - 1.69	8	1.22	0.37	0.63 - 1.73	8	1.21	0.38	0.65 - 1.73
		Horizontal		1.17	0.57	0.62 - 2.07		1.32	0.51	0.55 - 2.13		1.32	0.53	0.57 - 1.95
11 - 15	m	Vertical	6	0.87	0.48	0.35 - 1.78	6	2.18	0.62	1.54 - 3.22	6	2.09	0.62	1.35 - 2.80
		Horizontal		1.14	0.63	0.30 - 1.98		2.51	0.69	1.43 - 3.21		2.36	0.76	1.37 - 3.66
	f	Vertical	6	0.74	0.26	0.49 - 1.13	6	1.72	0.51	0.76 - 2.16	6	1.89	0.29	1.51 - 2.28
		Horizontal		0.86	0.26	0.40 - 1.07		1.78	0.34	1.35 - 2.34		1.79	0.21	1.54 - 2.13
16 - 20	m	Vertical	7	0.87	0.31	0.48 - 1.35	7	2.95	0.73	2.27 - 4.26	7	2.60	0.69	1.73 - 3.84
		Horizontal		0.95	0.40	0.57 - 1.53		3.08	0.42	2.37 - 3.56		2.83	0.89	1.69 - 4.43
	f	Vertical	5	0.66	0.32	0.35 - 1.21	5	1.69	0.34	1.27 - 2.16	5	1.50	0.35	1.20 - 2.02
		Horizontal		0.79	0.48	0.42 - 1.62		1.67	0.47	1.34 - 2.47		1.56	0.30	1.25 - 1.95
21 - 30	m	Vertical	6	0.83	0.26	0.52 - 1.15	6	3.18	0.54	2.18 - 3.66	6	3.11	0.29	2.66 - 3.47
		Horizontal		0.97	0.46	0.44 - 1.59		3.15	0.61	2.10 - 3.64		2.84	0.35	2.22 - 3.15
	f	Vertical	7	0.51	0.13	0.36 - 0.70	7	2.29	0.30	1.75 - 2.66	7	2.09	0.32	1.53 - 2.46
		Horizontal		0.58	0.20	0.34 - 0.89		2.59	0.31	2.27 - 3.11		2.35	0.23	1.93 - 2.68
31 - 50	m	Vertical	8	1.02	0.27	0.68 - 1.49	8	3.86	0.78	2.93 - 5.33	8	3.85	1.08	2.34 - 5.91
		Horizontal		0.96	0.34	0.63 - 1.69		4.35	0.93	3.46 - 5.69		4.30	0.79	3.41 - 5.45
	f	Vertical	8	0.82	0.24	0.47 - 1.15	8	2.41	0.59	1.03 - 2.89	8	2.45	0.60	1.18 - 3.11
		Horizontal		0.84	0.42	0.22 - 1.60		3.03	0.55	2.20 - 3.89		2.92	0.50	2.09 - 3.44
51 - 60	m	Vertical	4	0.74	0.10	0.62 - 0.85	4	3.00	0.75	2.20 - 4.01	4	2.87	0.40	2.41 - 3.37
		Horizontal		0.75	0.28	0.34 - 0.96		3.49	0.58	2.91 - 4.28		3.34	0.29	2.94 - 3.64
	f	Vertical	4	0.52	0.15	0.40 - 0.74	4	1.95	0.35	1.56 - 2.30	4	1.91	0.58	1.31 - 2.60
		Horizontal		0.51	0.04	0.47 - 0.56		2.36	0.06	2.27 - 2.42		2.35	0.28	1.96 - 2.60
61 - 70	m	Vertical	4	0.70	0.10	0.62 - 0.84	4	2.37	0.40	2.14 - 2.96	4	2.38	0.84	1.74 - 3.60
		Horizontal		0.68	0.06	0.60 - 0.74		3.57	0.78	2.50 - 4.26		3.35	0.84	2.43 - 4.37
	f	Vertical	14	0.49	0.10	0.30 - 0.64	14	1.64	0.41	0.94 - 2.54	14	1.58	0.46	0.85 - 2.67
		Horizontal		0.53	0.17	0.24 - 0.81		2.11	0.49	1.33 - 3.09		2.37	0.63	1.61 - 3.39
71 - 80	m	Vertical	9	0.66	0.26	0.32 - 1.03	9	2.47	0.56	1.51 - 3.20	9	2.24	0.64	1.21 - 3.24
		Horizontal		0.71	0.28	0.36 - 1.23		3.05	0.51	1.89 - 3.63		2.84	0.36	2.22 - 3.39
	f	Vertical	12	0.55	0.25	0.14 - 1.14	12	1.72	0.36	1.01 - 2.10	12	1.50	0.43	0.84 - 2.11
		Horizontal		0.49	0.18	0.23 - 0.89		2.20	0.44	1.61 - 2.79		2.24	0.50	1.50 - 2.91
81 - 90	m	Vertical	5	0.63	0.36	0.30 - 1.24	5	1.74	0.69	1.23 - 2.93	5	1.80	0.72	1.15 - 2.94
		Horizontal		0.45	0.13	0.31 - 0.63		2.11	0.88	1.28 - 3.53		1.81	1.11	0.40 - 3.35
	F	Vertical	8	0.51	0.33	0.22 - 1.24	8	1.36	0.31	0.90 - 1.71	8	1.29	0.38	0.80 - 1.89
		Horizontal		0.41	0.13	0.24 - 0.63		1.88	0.44	1.28 - 2.35		1.72	0.44	1.09 - 2.36

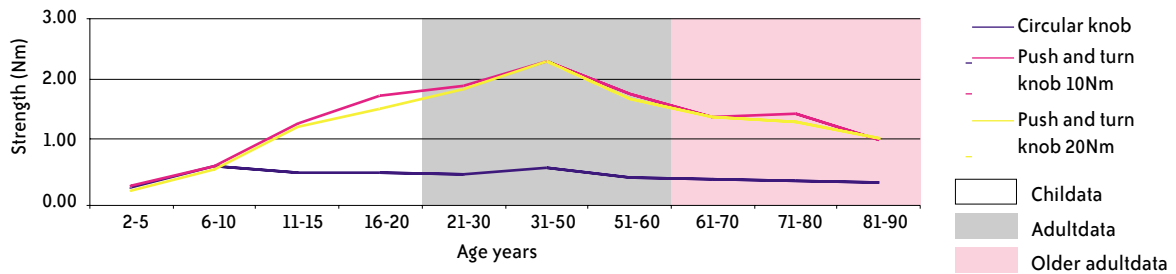
Mean maximum horizontal wrist twisting strength (males)



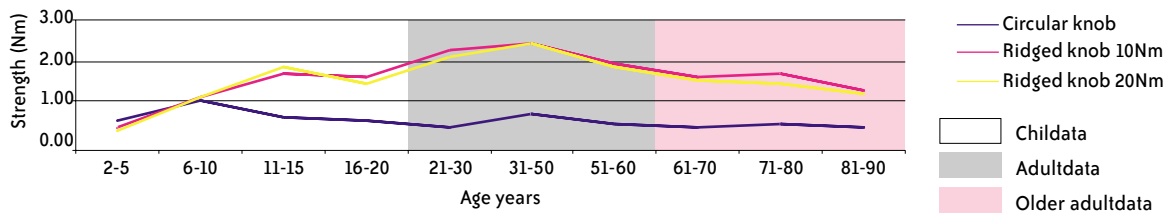
Mean maximum horizontal wrist twisting strength (females)



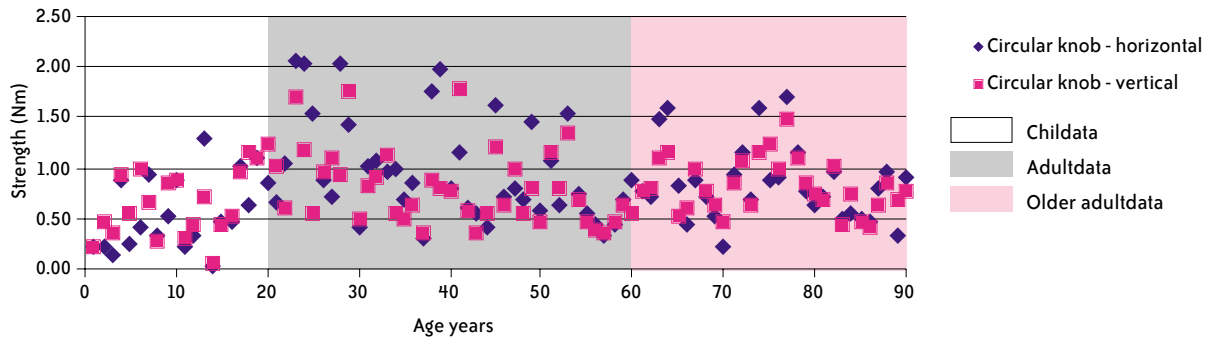
Mean maximum vertical wrist twisting strength (males)



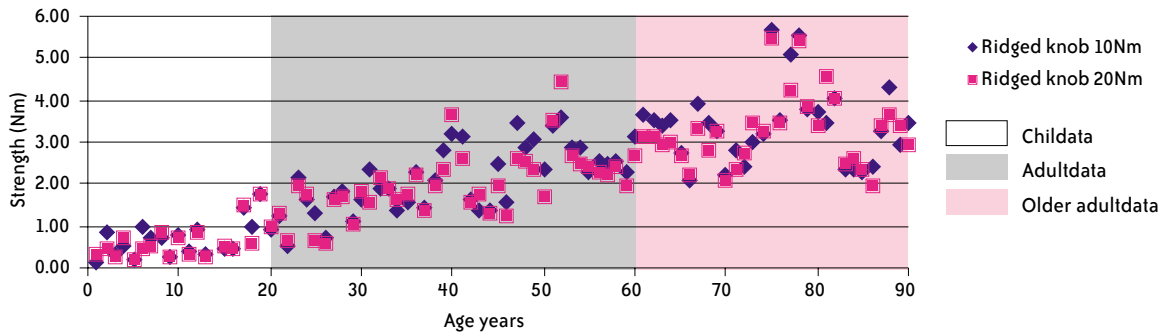
Mean maximum vertical wrist twisting strength (females)



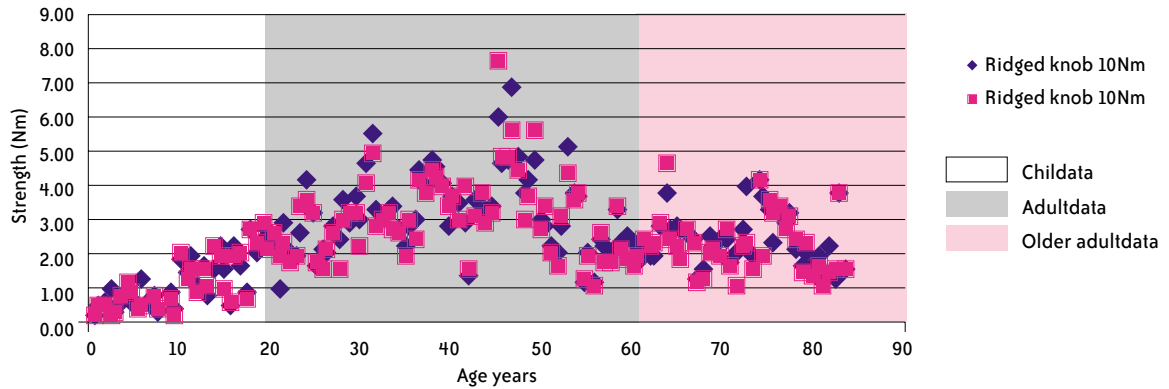
Maximum wrist twisting strength with circular knob



Maximum wrist twisting strength with the push and turn knob with resistances of 10N and 20N in horizontal position



Maximum wrist twisting strength with the push and turn knob with resistances of 10N and 20N in vertical position



6 Pull force on a can ring-pull

Description

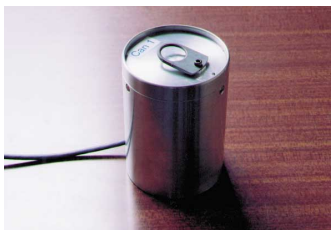
Maximum static pull strength when opening a can ring-pull, in Newtons (N).

Method

The subject stands in front of the measuring device and adopts a free posture. A maximum static pulling force is exerted using one hand on the ring-pull on a can (ie the ring pull doesn't move). The ring-pull is in two positions. The subjects can hold the can in any hand, and in any orientation. Subjects are instructed to build up their maximum strength in the first few seconds and to maintain maximum strength for a further few seconds.

Can type and size

Two custom-made replica cans, 100mm high and 75mm diameter, with a ring-pull 35mm long and 23mm (maximum) diameter. On can 1 the ring-pull is in the starting position, a space of 5mm between the ring-pull and the top of the can. On can 2 the ring-pull is at 75° angle to the top of the can.



Can 1



Measuring pulling force on can 1



Can 2



Measuring pulling force on can 2

Subject numbers

139 subject were measured

Age (Years)	Male	Female	Total
2-5	9	7	16
6-10	6	8	14
11-15	6	6	12
16-20	6	5	11
21-30	6	7	13
31-50	8	8	16
51-60	4	4	8
61-70	4	14	18
71-80	9	12	21
81-90	2	8	10
Total	60	79	139

Anthropometric variables (stature, weight, elbow height, hand length and hand breadth) for all subjects can be found in Appendix 6a.

Analysis

Effect of sex

In adults aged 16 years and over, males were generally found to be significantly stronger than females. No significant differences were found in pull force on the can ring-pull (vertical and horizontal) between males and females in children from 2-15 years and adults ages 71-90 (Appendix 6b).

Effect of age

Maximum strength for both ring-pulls generally increases throughout childhood (2-15 years), it peaks in adulthood, and then decreases with age from around 50 years. Some significant differences were found between the age groups for both horizontal and vertical conditions, although 2-5 year olds were significantly weaker than all other age groups on both ring-pulls (Appendix 6c).

Effect of orientation of can ring-pull.

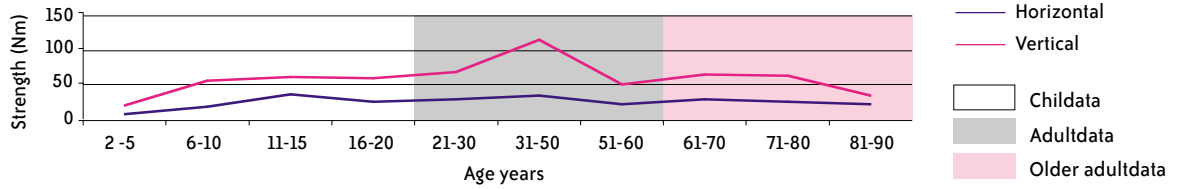
The orientation of the handles appears to significantly effect maximum strength for both males and females with the higher strength forces being exerted when the can ring-pull was in the vertical orientation (Appendix 6d). Correlation coefficients for all measurements can be found in Appendix 6e.

Results

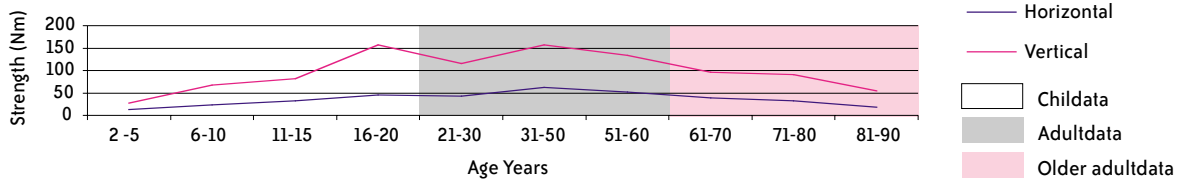
Pull strength on a can ring-pull

Age (yrs)	Sex	Horizontal ring-pull (N)				Vertical ring-pull (N)			
		No.	Mean	SD	Range	No.	Mean	SD	Range
2 – 5	m	9	12.38	6.17	5.57 - 23.27	9	27.08	14.33	6.84 - 47.14
	f	7	7.66	1.19	5.96 - 9.30	7	19.50	11.58	5.11 - 38.50
6 – 10	m	6	23.02	8.49	17.43 - 38.34	6	68.02	27.62	29.06 - 95.50
	f	8	17.36	9.17	9.45 - 38.64	8	53.95	31.37	21.34 - 103.56
11 – 15	m	6	32.59	16.43	10.07 - 48.77	6	82.24	44.40	23.76 - 153.54
	f	6	34.54	13.85	20.32 - 59.85	6	59.81	18.88	34.47 - 87.21
16 – 20	m	6	45.69	14.67	25.20 - 68.43	6	157.34	53.35	59.92 - 199.14
	f	5	24.67	15.26	8.37 - 49.48	5	57.80	47.62	30.67 - 141.56
21 - 30	m	6	42.51	11.42	29.11 - 56.51	6	115.08	23.27	82.84 - 149.62
	f	7	28.57	4.87	19.57 - 34.47	7	66.99	8.72	53.70 - 79.38
31 – 50	m	8	62.03	30.60	34.11 - 111.74	8	156.78	87.75	2.23 - 277.79
	f	8	32.36	10.91	17.88 - 48.08	8	111.93	66.95	42.76 - 254.18
51 – 60	m	4	51.89	20.69	25.20 - 71.17	4	133.33	42.45	70.05 - 160.68
	f	4	21.51	2.90	19.19 - 25.68	4	48.95	20.40	22.50 - 70.17
61 – 70	m	4	39.52	9.99	28.63 - 50.85	4	95.67	21.53	71.44 - 114.04
	f	14	27.08	9.65	8.28 - 46.89	14	62.20	18.68	28.83 - 94.81
71 - 80	m	9	32.31	9.27	16.21 - 42.21	9	91.37	42.21	49.21 - 177.49
	f	12	24.94	10.48	12.10 - 45.49	12	61.20	27.36	30.90 - 114.16
81 – 90	m	2	18.23	1.43	17.22 - 19.25	2	54.57	23.86	37.70 - 71.44
	f	8	20.43	9.12	5.16 - 32.35	8	33.75	5.42	28.25 - 40.92

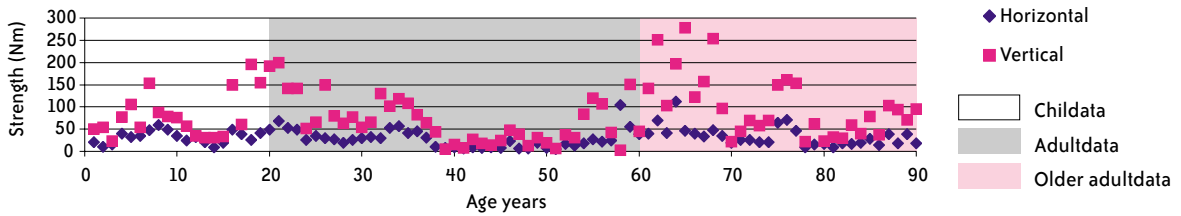
Mean maximum pulling strength on can ring-pull (males)



Mean maximum pulling strength on can ring-pull (females)



Maximum pulling strength on can ring-pull



7 Press and lift with the foot

Description

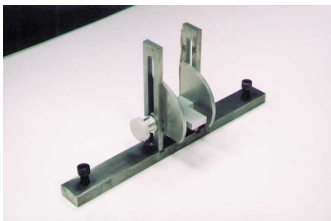
Maximum static pressing and lifting strength with the foot on a bar and a pedal, in Newtons (N).

Method

The subject stands in front of the measuring device and adopts a free posture. A maximum static pressing and lifting force is exerted with one (dominant) foot on a bar and a pedal, placed at the subject's instep height (the highest point on the top of the foot). Subjects are instructed to build up their maximum strength in the first few seconds and to maintain maximum strength for a further few seconds.

Pedal type and size

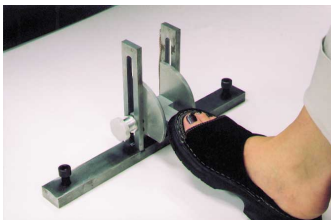
A pedal 400mm length and 30mm wide, placed inside a 55mm wide space to restrict the amount of the foot that can be placed onto the pedal. A bar, 250mm long and 20mm diameter. The pedals were designed to represent those used as brake pedals on pushchairs.



Pedal for measuring press and lift with the foot



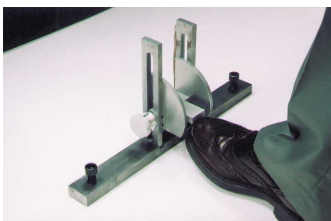
Bar for measuring press and lift with the foot



Measuring press strength on the pedal



Measuring press strength on the bar



Measuring lift strength on the pedal



Measuring lift strength on the bar

Subject numbers

140 subjects were measured

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 7a.

Analysis

Effect of sex

Males were found to be significantly stronger than females between ages 16 to 20 and in most conditions from 31 to 70 years (Appendix 7b).

Effect of age

For both the pressing and lifting of the bar and pedal maximum strength generally increases from childhood (2-15 years) peaking in adulthood and begins decreasing from around 50 years. Some significant differences were found between the age groups (Appendix 7c).

Effect of pressing or lifting with the foot on pedal and bar type

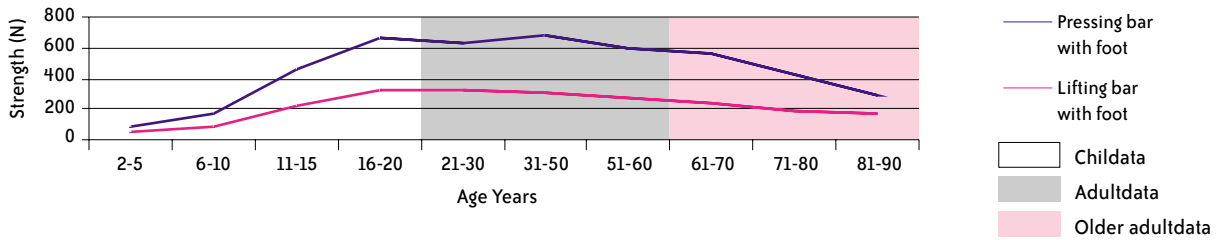
A significant difference was found between pressing and lifting with the foot on the pedal and the bar. Pressing on both the bar and the pedal gave higher mean maximum forces than lifting for both males and females. Also the bar yielded higher mean maximum forces than the pedal for both pressing and lifting for males and females (Appendix 7d). Correlation coefficients for all measurements can be found in Appendix 7e.

Results

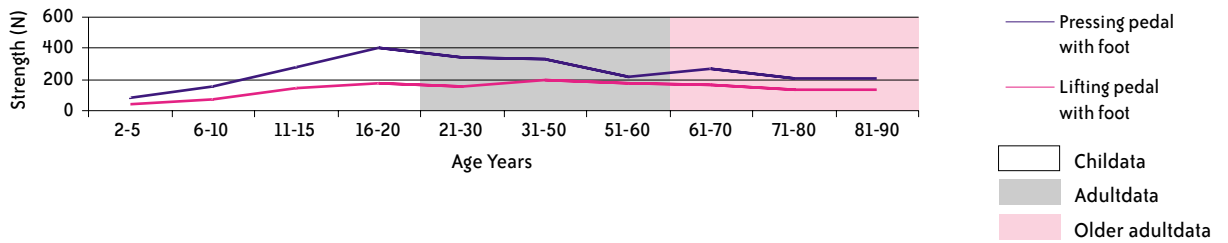
Press and lift strength with the foot

Age (years)	Sex	Condition	Bar (N)				Pedal (N)			
			No.	Mean	SD	Range	No.	Mean	SD	Range
2 – 5	m	Lift	9	46.43	15.55	18.20 - 63.00	9	42.57	12.32	23.20 - 58.10
		Press		93.49	29.48	44.30 - 137.00		79.17	35.39	18.50 - 126.70
	f	Lift	8	48.69	16.92	18.20 - 63.00	8	33.15	13.02	23.20 - 63.00
		Press		84.84	33.43	44.30 - 147.30		80.31	33.59	39.10 - 131.80
6 – 10	m	Lift	5	89.96	35.35	58.10 - 142.80	5	72.02	24.26	48.10 - 102.90
		Press		169.90	40.48	100.90 - 203.90		151.36	38.90	106.10 - 198.70
	f	Lift	8	133.41	41.64	73.00 - 192.60	8	97.95	36.33	43.10 - 147.80
		Press		232.86	124.73	95.80 - 466.50		162.71	64.07	75.20 - 276.00
11 – 15	m	Lift	7	223.94	69.03	117.90 - 342.10	7	142.77	45.94	48.10 - 197.60
		Press		466.44	125.98	250.20 - 636.40		280.40	78.38	147.30 - 384.10
	f	Lift	5	178.66	50.52	147.80 - 267.40	5	118.86	44.19	83.00 - 182.60
		Press		428.38	26.66	394.40 - 466.50		197.72	107.59	111.20 - 373.80
16 – 20	m	Lift	7	327.14	56.45	242.40 - 416.80	7	172.69	52.02	117.90 - 252.40
		Press		657.69	129.04	476.80 - 898.90		407.61	177.69	167.80 - 667.20
	f	Lift	5	180.64	80.23	102.90 - 302.20	5	98.90	35.13	63.00 - 152.70
		Press		403.64	116.68	296.60 - 590.00		216.26	128.59	85.50 - 415.00
21 – 30	m	Lift	7	320.04	99.37	147.80 - 441.80	7	155.59	33.65	107.90 - 212.50
		Press		632.67	178.44	399.50 - 873.20		341.44	137.94	147.30 - 564.30
	f	Lift	6	228.32	49.56	142.80 - 277.30	6	136.13	31.47	83.00 - 177.70
		Press		469.02	64.62	389.20 - 528.20		227.05	66.33	167.80 - 332.60
31 – 50	m	Lift	9	309.42	49.20	247.40 - 391.90	9	200.36	39.40	157.70 - 282.30
		Press		672.96	137.85	461.30 - 873.20		329.18	129.99	173.00 - 579.70
	f	Lift	8	210.65	59.26	127.80 - 312.20	8	129.70	24.42	92.90 - 167.70
		Press		519.24	189.74	209.00 - 754.80		237.99	106.80	121.50 - 435.60
51 - 60	m	Lift	4	279.80	78.71	197.60 - 386.90	4	176.43	31.89	137.80 - 202.60
		Press		592.60	162.50	435.60 - 811.40		215.45	41.04	162.70 - 260.50
	f	Lift	4	145.28	42.40	102.90 - 202.60	4	109.13	31.60	78.00 - 152.70
		Press		351.93	92.91	245.10 - 466.50		243.78	45.15	193.60 - 291.40
61 – 70	m	Lift	5	245.44	42.07	207.60 - 317.20	5	160.72	21.60	142.80 - 197.60
		Press		559.12	126.11	451.00 - 770.20		267.74	66.40	173.00 - 342.90
	f	Lift	14	155.59	39.31	112.90 - 252.40	14	120.71	22.01	78.00 - 147.80
		Press		337.39	94.73	106.10 - 512.80		183.29	57.68	70.00 - 276.00
71 – 80	m	Lift	9	182.63	53.43	73.00 - 242.40	9	131.14	38.61	63.00 - 197.60
		Press		417.86	112.80	296.60 - 605.50		205.02	95.68	85.50 - 399.50
	f	Lift	13	139.71	38.80	38.10 - 182.60	13	128.58	25.64	92.90 - 162.70
		Press		357.15	71.56	214.20 - 481.90		214.98	67.87	111.20 - 378.90
81 – 90	m	Lift	2	162.70	49.36	127.80 - 197.60	2	132.80	70.43	83.00 - 182.60
		Press		296.55	72.76	245.10 - 348.00		211.65	91.00	147.30 - 276.00
	f	Lift	5	117.86	33.27	63.00 - 147.80	5	107.88	52.13	48.10 - 187.60
		Press		256.40	106.96	157.60 - 430.40		151.40	25.57	126.70 - 193.60

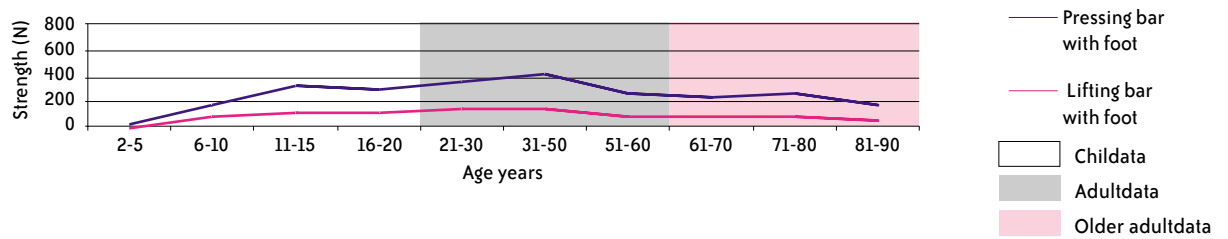
Mean maximum pressing and lifting strength with the foot on the bar (males)



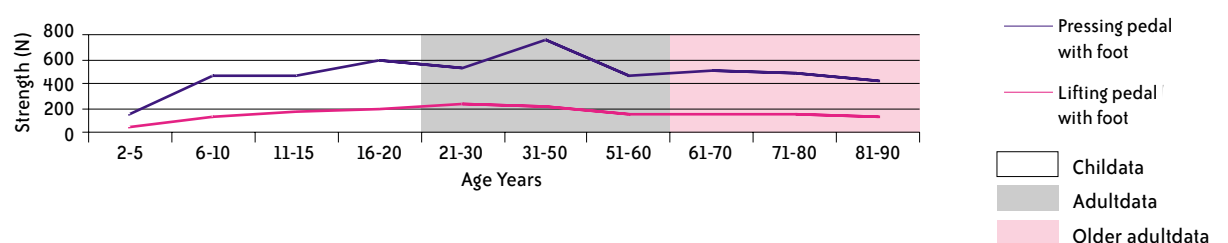
Mean maximum pressing and lifting strength with the foot on the pedal (males)



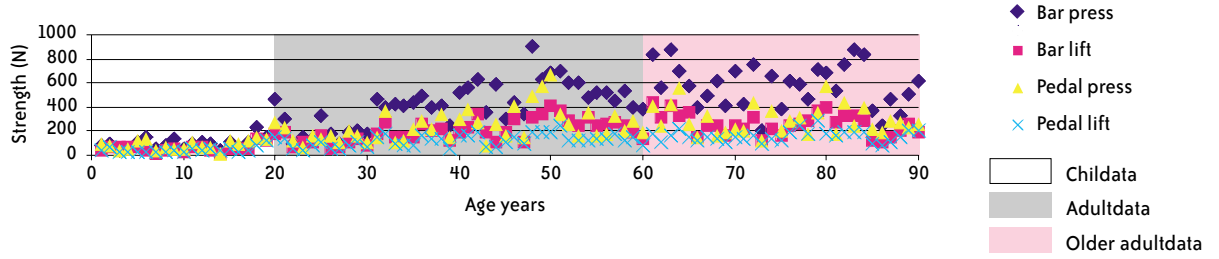
Mean maximum pressing and lifting strength with the foot on the bar (females)



Mean maximum pressing and lifting strength with the foot on the pedal (females)



Maximum pressing and lifting strength with the foot



8 Pull on 20mm knob

Description

Maximum static pulling strength using one and two hands on a small round knob, in Newtons (N).

Method

The subject stands in front of the measuring device and adopts a free posture. A maximum static pulling force is exerted using both one (dominant) hand and both hands on the knob. 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 round knob, 20mm diameter and 20mm depth.



20 mm knob



Experimental trial: pulling on the 20mm knob

Subject numbers

140 subjects were measured:

Age (Years)	Male	Female	Total
2 - 5	9	8	17
6 -10	5	8	13
11 - 15	7	6	13
16 - 20	8	4	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	4	6
Total	65	75	140

Anthropometric variables (stature, weight, elbow height, hand length and hand breadth) for all subjects can be found in Appendix 8a.

Analysis

Effect of sex

No significant difference in pulling strength was found between males and females except at ages 16-20 and 21-30 (this latter group with 1 hand only) (Appendix 8b).

Effect of age

Strength generally increases in females up to age group 31 to 50, then gradually decreases with age from around 50 years, although with a slight decrease in the 16 to 20 age group. Strength gradually increases in males through childhood, peaks in the 16 to 20 age group and then gradually decreases. This decrease could be due to finger size and difficulty with manipulation of the knob. The only significant differences were between children 2-15 years and the older age groups (Appendix 8c).

Effect of the number of hands used

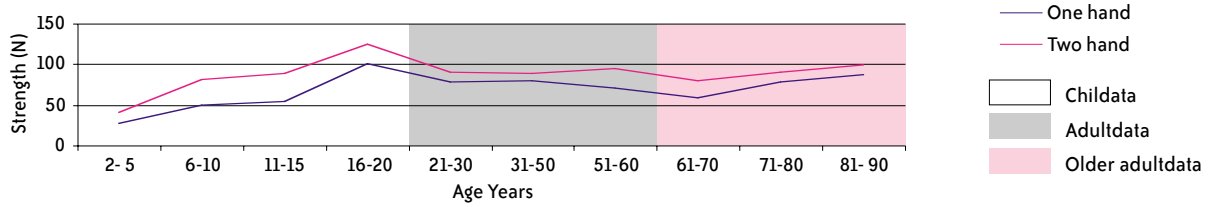
The number of hands used appears to significantly affect maximum strength, with two hands generating higher forces for both males and females (Appendix 8d). Correlation coefficients for all measurements can be found in Appendix 8e.

Results

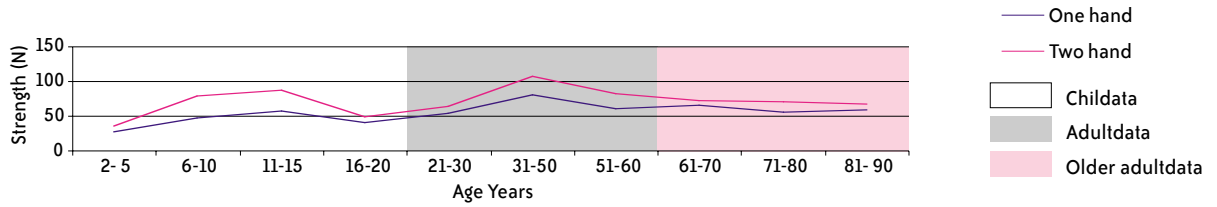
Pull strength on 20mm knob

Age (yrs)	Sex	Pull on 20mm knob with one hand (N)				Pull on 20mm knob with two hands (N)			
		No.	Mean	SD	Range	No.	Mean	SD	Range
2 – 5	m	9	27.61	10.37	15.40 - 51.80	9	41.20	19.00	16.10 - 74.70
	f	8	26.93	10.77	15.20 - 42.60	8	35.63	8.51	22.30 - 49.90
6 – 10	m	5	49.62	8.89	41.10 - 63.10	5	80.64	18.66	59.30 - 109.10
	f	8	46.26	9.14	25.60 - 53.40	7	78.63	19.65	44.80 - 102.50
11 – 15	m	7	53.26	16.54	36.70 - 85.40	7	88.63	37.23	47.80 - 161.20
	f	6	56.57	12.04	46.00 - 72.90	6	86.68	38.30	56.90 - 161.50
16 – 20	m	8	100.50	27.41	53.90 - 137.70	8	125.03	36.65	56.70 - 167.90
	f	4	39.68	15.64	20.10 - 54.40	4	48.78	14.91	27.40 - 60.50
21 - 30	m	7	77.73	15.33	62.30 - 103.80	7	89.57	47.41	58.40 - 195.00
	f	6	54.05	12.85	44.20 - 74.40	6	63.13	15.34	51.30 - 86.20
31 – 50	m	9	80.07	42.10	42.00 - 163.50	9	87.80	44.86	41.40 - 188.90
	f	8	80.53	34.77	44.80 - 140.40	8	106.01	41.47	44.70 - 187.60
51 – 60	m	4	70.23	22.57	45.10 - 100.00	4	94.58	7.68	87.90 - 103.80
	f	4	59.98	14.08	39.00 - 69.30	4	81.00	27.02	47.70 - 113.80
61 – 70	m	5	58.26	14.34	47.70 - 83.30	5	78.76	25.87	50.90 - 105.00
	f	14	64.44	28.02	34.10 - 144.00	14	72.28	33.09	21.10 - 151.20
71 - 80	m	9	77.68	36.18	28.50 - 138.80	9	89.32	32.42	54.20 - 156.70
	f	13	55.17	16.73	35.10 - 84.80	13	70.57	22.08	38.50 - 105.20
81 – 90	m	2	87.35	25.24	69.50 - 105.20	2	99.20	83.01	40.50 - 157.90
	f	4	58.05	21.45	37.90 - 87.30	5	67.24	9.01	58.30 - 79.90

Mean maximum pulling strength on the 20mm knob (males)



Mean maximum pulling strength on the 20mm knob (females)



Maximum pulling strength on the 20mm knob with one hand and two hands

