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RESEARCH ARTICLE

Lengths, girths, and diameters of children's fingers from 3 to 10 years of age

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ABSTRACT

We obtained data on the lengths, girths, and diameters of the fingers of children from 3 to 10 years of age.

A total of 160 children (78 girls, 82 boys) were examined in a cross-sectional investigation. The length of each finger of the right hand of every child was measured, as were the girths of the proximal, middle, and distal phalanges, and of the proximal and distal interphalangeal joint.

The average length of the thumb was 49 (35–65) mm. The index and ring fingers both averaged 69 (index, 50–88; ring, 42–96) mm in length, while the middle and little fingers averaged 72 (57–100) and 56 (40–74) mm, respectively. Average diameter, calculated from the girth measurement, was 16 (11–22) mm for the thumb, 15 mm for both the index (9–22) and middle (10–21) fingers, 14 (10–20) and 13 (8–19) mm for the ring and little fingers, respectively. The average length of each finger increased by 37% from 3 to 10 years of age, average girth by 24%, and diameter increased by 20%. We observed no differences in length, girth, and diameter between the sexes.

The dimensions of children's fingers are relevant to injuries from automatic, power-operated window lifters of motor vehicles because risk of injury to a finger jammed between an ascending window and the seal entry depends upon the diameter of the finger. Additionally, short fingers of young children can be jammed over almost their entire length in the oblique design of a car window seal entry.

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1. Introduction

Beginning in 1963, automobile windows could be opened and closed at the push of a button by an electric motor. In 1986 closing force restriction began to be incorporated in power window designs, although under current statutory provisions closing force restriction systems are active only over a distance of 4–200 mm between window and seal. Under 4 mm, closing force restriction is disengaged to press the window glass into the seal entry for air and watertight closure. Upon closing, a force of up to 500 N, which corresponds to a weight of 50 kg, can occur. An object caught in the gap between window glass and seal entry, such as a small child's finger, can be jammed and injured, and due to the design of the seal entry such objects need not be as small as 4 mm. The current state of the art also allows remote window activation, as for door locks, using a transmitter in the vehicle key. This capability worsens the hazard to children because not all power windows that can be remotely operated have closing force restriction. International guidelines set a value of 100 N for maximum window closing force, but this value, which is intended to prevent child strangulation, is not based upon published scientific results, and no boundary value for the protection of fingers, especially those of children, exists. Not surprisingly, finger injuries in children are frequently caused by jam events (Bhende et al., 1993; Brandmair et al., 1980; Claudet et al., 2007; Doraiswamy and Baig, 2000; Doraiswamy, 1999; Giddins and Hill, 1998; Macgregor and Hiscox, 1999; Salazard et al., 2004), which can happen if children hold their fingers between mechanically moving parts such as the window glass and seal entry of a motor vehicle side door window (Fig. 1). The US National Highway Traffic Safety Administration (2009) estimated an incidence of 2000 injuries in 2007 due to closing vehicle windows.

Doraiswamy (1999) and Doraiswamy and Baig (2000) found that most such jam injuries occurred in young children (38% to children under 5 years, 32% aged 5–10 years).

Although it is apparent that dimensions of the fingers of small children put them at risk of injury by automobile power windows, precise data on these dimensions are sparse. In order to improve the quality of protection systems and to minimize the danger of

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Fig. 1. A child grasps the edge of the window in the danger area between window glass and seal entry of a motor vehicle side door.

injury, especially to children's fingers, an empirically based boundary value for the closing force of power-operated window lifters is needed.

Because the dimensions of children's injury-prone fingers are relevant to such a value, we determined lengths, girths, and diameters of the fingers of children from 3 to 10 years of age.

2. Methods

2.1. Test subjects/volunteers

A total of 160 children (78 girls, 82 boys), 3–10 years of age were examined in a cross-sectional investigation in November 2008 and January 2009. Twenty children of each respective age group from 3 to 10 years were selected by chance from the 373 children in two kindergartens and a primary school in Bavaria, Germany by a school nurse or secretary. All children were of German nationality. Informed consent was granted by parents of the children who participated and the procedures were approved by the ethics committee (Ethik-Kommission der Bayrischen Landesärztekammer, Nr. 10002) and conformed to the Declaration of Helsinki. The children were normally developed for their age and had normal hands without congenital disorders. They had normal weights by visual inspection; weight and body-mass-index were not otherwise determined. Children were questioned about handedness, which all were able to indicate; handedness was confirmed for all kindergarten children by an educator. Right dominance was observed in 18 (90%) of the 3, 7, 8, and 10 year-old groups, 16 (80%) of the 4 and 6 year-olds, 20 (100%) of the 5 year-olds, and 15 (75%) of the 9 year-old children. The measurements were performed during instruction and in the kindergartens in a separate room. The children sat beside the examiner with the hand on a table. All data were directly collected in a notebook. For every child, the length of each finger and the girth of the proximal, middle, and distal phalanx, and of the proximal and distal interphalangeal joint of the right hand were measured using a customary measuring tape. The length of each finger including the thumb was measured from the dorsal joint space of the metacarpophalangeal joint to the distal nail edge. The girth of each finger was similarly measured in the middle of the proximal, middle, and distal phalanx, as well as at the joint spaces of the proximal and distal interphalangeal joint in neutral position. Diameter was calculated from girth, which was assumed to be circular. All measurements were carried out by one examiner (B.H.).

3. Results

Table 1 shows the measured lengths, girths, and calculated diameters of all children's fingers, Table 2 the boys' measurements and Table 3 those of the girls. All finger dimensions increased with age. Finger girth (and diameter) decreased in all age-groups from proximal to distal. The girths of the proximal phalanges decreased from the thumb to the small finger. In comparison to the adjacent fingers, the proximal interphalangeal joint and the middle phalanges of the middle finger had the largest girth. The distal interphalangeal joint and distal phalanx of the thumb had the largest girth, followed by the middle, index, ring, and little fingers. The distal phalanges and the little finger had the smallest girth and diameter. The middle finger was the longest, the thumb the shortest in all age-groups. The average length of the thumb was 49 (range 35–65) mm. The index and ring fingers both averaged 69 (index, 50–88; ring, 42–96) mm in length, while the middle and little fingers averaged 72 (57–100) and 56 (40–74) mm, respectively. Average diameter, calculated from the girth measurement, was 16 (11–22) mm for the thumb, 15 mm for both the index (9–22) and middle (10–21) fingers, 14 (10–20) and 13 (8–19) mm for the ring and little fingers, respectively. The average length of each finger increased by 37% from age 3 to 10, average girth by 24%, and diameter increased by 20%.

There were no differences between the sexes for length, girth, and diameter. The average length of the thumb was 49 mm for boys (48 mm for girls). The average length of the index finger was 68 mm for boys and 69 mm for girls; the middle finger, 75 mm for boys (77 mm for girls); the ring finger, 70 mm for boys, 72 mm for girls; and the average length of the little finger was 55 mm for boys, 56 mm for girls. The average diameter of the thumb was 17 mm for both sexes. The average diameter of the index finger was 15 mm for boys and 14 mm for girls; the middle finger, 15 mm for both boys and girls; the ring finger was 14 mm for both boys and girls; and the average diameter of the little finger was 13 mm for both boys and girls.

4. Discussion

This investigation is the first to determine the dimensions of three-phalangeal fingers of children along with the thumb. Only Goldfarb et al. (2005) have examined relative thumb length, girth, and nail width, in 273 volunteers aged 1–18 years. In contrast to this study, Goldfarb et al. measured girth only at the level of the interphalangeal joint of the thumb and the proximal interphalangeal joint of the index finger, and calculated their ratio. Weiss and Flatt (1971) examined relations between hand and finger lengths in relation to pinch strength in a pilot study with 198 schoolchildren aged 5–13 years. However, the authors reported no length values. Loehlin et al. (2009) and Manning et al. (2004) investigated relative finger length of children and calculated the ratio between the length of the index and ring finger, although in contrast to the results of Loehlin et al. and Manning et al. no differences between the sexes were observed in this study.

Our data affirm that the current designs and operational safeguards of automobile power windows put the small fingers of children at risk of injury. The seal design of modern motor vehicles power windows clearly allows a larger actual gap than the minimum statutory distance of 4 mm at which closing force restriction is disengaged. If a child grasps the edge of an open window in a motor vehicle side door, jam injuries are possible if the fingers are not removed from the danger area between window glass and seal entry. An automobile window can close at a speed of 10 cm/s with a closing force of up to 500 N, which is

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Table 1
Measured finger length and girth, and calculated diameter for children 3–10 years of age.

Finger	Age (years)	Median (range) (mm)										
		Girth					Length	Diameter				
		PP	PIP	MP	DIP	DP		PP	PIP	MP	DIP	DP
Thumb	3	50 (45–56)			46 (42–50)	39 (33–45)	40 (35–45)	16 (14–18)			15 (13–16)	12 (11–14)
	4	50 (40–60)			48 (38–53)	40 (30–48)	43.5 (38–51)	16 (13–19)			15 (12–17)	13 (10–15)
	5	52 (48–58)			49 (44–56)	40 (38–45)	45 (41–55)	17 (15–18)			16 (14–18)	13 (12–14)
	6	53 (50–58)			52 (48–57)	43 (40–48)	47.5 (41–58)	17 (16–18)			17 (15–18)	14 (13–15)
	7	54 (50–66)			52.5 (48–58)	45 (40–50)	50 (41–55)	17 (16–21)			17 (15–18)	14 (13–16)
	8	56 (48–60)			54 (43–58)	48 (43–52)	52 (47–60)	18 (15–19)			17 (14–18)	15 (14–17)
	9	58 (51–65)			56 (50–64)	48 (44–55)	56 (46–65)	19 (16–21)			18 (16–20)	15 (14–18)
	10	60 (55–68)			57 (53–62)	49.5 (43–58)	54 (50–60)	19 (18–22)			18 (17–20)	16 (14–18)
Increase from 3 to 10 years in mm (%)		10 (20)			11 (24)	10.5 (27)	14 (35)	3 (19)			3 (20)	4 (33)
Index	3	48 (43–55)	46 (41–48)	40 (37–45)	38 (33–40)	33 (29–36)	57 (50–62)	15 (14–18)	15 (13–15)	13 (12–14)	12 (11–13)	11 (9–11)
	4	50 (43–56)	47.5 (40–50)	41.5 (35–45)	38 (33–43)	34 (28–37)	61 (52–68)	16 (14–18)	15 (13–16)	13 (11–14)	12 (11–14)	11 (9–12)
	5	50 (46–56)	48,5 (43–55)	43 (37–47)	40 (37–45)	34,5 (31–38)	64,5 (59–67)	16 (15–18)	15 (14–18)	14 (12–15)	13 (12–14)	11 (10–12)
	6	52 (45–58)	50 (46–55)	44.5 (41–51)	42.5 (38–48)	37.5 (32–43)	67 (60–77)	17 (14–18)	16 (15–18)	14 (13–16)	14 (12–15)	12 (10–14)
	7	53 (48–65)	51 (48–57)	46 (42–50)	43 (40–48)	38 (35–42)	70.5 (60–82)	17 (15–21)	16 (15–18)	15 (13–16)	14 (13–15)	12 (11–13)
	8	54 (48–60)	52 (48–58)	47.5 (44–50)	44 (39–46)	39.5 (37–45)	71.5 (68–82)	17 (15–19)	17 (15–18)	15 (14–16)	14 (12–15)	13 (12–14)
	9	56.5 (51–65)	55 (50–60)	49 (45–60)	45 (40–52)	40 (36–45)	80 (68–88)	18 (16–21)	18 (16–19)	16 (14–19)	14 (13–17)	13 (11–14)
	10	60 (54–70)	55 (51–62)	50 (46–55)	45 (42–50)	41 (35–45)	79 (70–88)	19 (17–22)	18 (16–20)	16 (15–18)	14 (13–16)	13 (11–14)
Increase from 3 to 10 years in mm (%)		12 (25)	9 (20)	10 (25)	7 (18)	8 (24)	22 (39)	4 (27)	3 (20)	3 (23)	2 (17)	2 (18)
Middle	3	48 (40–50)	46 (42–50)	42 (38–45)	38 (35–40)	34 (30–38)	63 (57–69)	15 (13–16)	15 (13–16)	13 (12–14)	12 (11–13)	11 (10–12)
	4	49 (42–52)	48 (42–52)	42.5 (38–47)	40 (35–45)	36 (32–38)	67 (60–74)	16 (13–17)	15 (13–17)	14 (12–15)	13 (11–14)	11 (10–12)
	5	50 (45–54)	48 (44–55)	44.5 (40–49)	42 (38–45)	37 (34–40)	72.5 (63–80)	16 (14–17)	15 (14–18)	14 (13–16)	13 (12–14)	12 (11–13)
	6	51 (46–58)	50.5 (47–56)	46 (40–50)	43 (40–48)	39 (33–42)	74.5 (68–88)	16 (15–18)	16 (15–18)	15 (13–16)	14 (13–15)	12 (11–13)
	7	52.5 (47–65)	52.5 (47–57)	47 (42–55)	44 (40–50)	40 (35–44)	77 (66–90)	17 (15–21)	17 (15–18)	15 (13–18)	14 (13–16)	13 (11–14)
	8	52.5 (47–60)	53 (48–60)	48 (42–53)	45 (40–48)	41.5 (39–45)	80.5 (72–90)	17 (15–19)	17 (15–19)	15 (13–17)	14 (13–15)	13 (12–14)
	9	55 (49–65)	56.5 (50–61)	50 (45–55)	46 (42–50)	42 (38–48)	87 (74–100)	18 (16–21)	18 (16–19)	16 (14–18)	15 (13–16)	13 (12–15)
	10	59.5 (52–65)	55 (52–60)	50 (46–57)	46.5 (43–50)	44 (38–59)	86 (87–100)	19 (17–21)	18 (17–19)	16 (15–18)	15 (14–16)	14 (12–19)
Increase from 3 to 10 years in mm (%)		11.5 (24)	9 (20)	8 (19)	8.5 (22)	10 (29)	23 (37)	4 (27)	3 (20)	3 (23)	3 (25)	3 (27)
Ring	3	45 (41–50)	44 (40–48)	40 (35–44)	37 (34–42)	33 (31–36)	60 (42–65)	14 (13–16)	14 (13–15)	13 (11–14)	12 (11–13)	11 (10–11)
	4	46 (42–50)	45 (40–50)	40 (36–45)	38 (34–42)	34.5 (32–38)	63.5 (55–74)	15 (13–16)	14 (13–16)	13 (11–14)	12 (11–13)	11 (10–12)
	5	48 (43–52)	46.5 (43–58)	43 (40–48)	39 (30–43)	35 (33–40)	69 (60–76)	15 (14–17)	15 (14–18)	14 (13–15)	12 (10–14)	11 (11–13)
	6	49.5 (44–55)	48.5 (44–53)	43 (40–48)	40 (37–43)	37 (34–41)	70 (62–85)	16 (14–18)	15 (14–17)	14 (13–15)	13 (12–14)	12 (11–13)
	7	50 (45–62)	50 (45–55)	43.5 (40–50)	40 (38–45)	38 (34–43)	71.5 (58–84)	16 (14–20)	16 (14–18)	14 (13–16)	13 (12–14)	12 (11–14)
	8	50.5 (46–57)	50 (45–58)	45 (40–50)	42 (39–45)	40 (38–42)	74.5 (67–83)	16 (15–18)	16 (14–18)	14 (13–16)	14 (12–14)	13 (12–13)
	9	55 (49–62)	50.5 (49–59)	45 (43–53)	44 (40–50)	40.5 (36–45)	83 (72–93)	18 (16–20)	16 (16–19)	14 (14–17)	14 (13–16)	13 (11–14)
	10	56 (50–60)	54.5 (50–58)	48 (42–53)	44.5 (40–48)	42 (35–43)	81 (70–96)	18 (16–19)	17 (16–18)	15 (13–17)	14 (13–15)	13 (11–14)
Increase from 3 to 10 years in mm (%)		11 (24)	11.5 (26)	8 (20)	7.5 (20)	9 (27)	21 (35)	4 (29)	3 (21)	2 (15)	2 (17)	2 (18)
Little	3	40 (38–45)	39 (37–42)	36 (32–38)	34 (30–35)	28 (26–32)	46 (40–50)	13 (12–14)	12 (12–13)	11 (10–12)	11 (10–11)	9 (8–10)
	4	40 (38–47)	40 (37–44)	37 (32–42)	34.5 (30–40)	30 (27–34)	50 (43–67)	13 (12–15)	13 (12–14)	12 (10–13)	11 (10–11)	10 (9–11)
	5	44 (40–48)	42 (38–46)	38 (35–41)	35.5 (34–40)	31 (28–38)	53 (45–63)	14 (13–15)	13 (12–15)	12 (11–13)	11 (11–13)	10 (9–12)
	6	45 (40–53)	43 (38–50)	40 (35–43)	38 (33–40)	33.5 (28–36)	54.5 (47–63)	14 (13–17)	14 (12–16)	13 (11–14)	12 (11–13)	11 (9–11)
	7	45.5 (40–50)	44.5 (40–50)	40 (37–45)	38 (35–42)	33.5 (30–39)	56.5 (47–65)	14 (13–16)	14 (13–16)	13 (12–14)	12 (11–13)	11 (10–12)
	8	45 (41–50)	44.5 (40–49)	40 (35–44)	39 (35–42)	35 (32–38)	59 (50–68)	14 (13–16)	14 (13–16)	13 (11–14)	12 (11–13)	11 (10–12)
	9	48.5 (44–60)	45 (43–56)	43.5 (38–55)	40 (36–45)	36 (33–40)	64.5 (55–74)	15 (14–19)	14 (14–18)	14 (12–18)	13 (11–14)	11 (11–13)
	10	50 (42–57)	48 (43–51)	43 (40–47)	40 (38–45)	36.5 (33–43)	63 (55–73)	16 (13–18)	15 (14–16)	14 (13–15)	13 (12–14)	12 (11–14)
Increase from 3 to 10 years in mm (%)		10 (25)	9 (23)	7 (19)	6 (18)	8.5 (30)	17 (37)	3 (23)	3 (25)	3 (27)	2 (18)	3 (33)

PP = proximal phalanx; PIP = proximal interphalangeal joint; MP = middle phalanx; DIP = distal interphalangeal joint; DP = distal phalanx

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Table 2
Measured finger length and girth, and calculated diameter for boys 3–10 years of age.

Finger	Age (years)	Median (range) (mm)										
		Girth					Length	Diameter				
		PP	PIP	MP	DIP	DP		PP	PIP	MP	DIP	DP
Thumb	3	51 (45–56)			48 (42–50)	41.5 (33–45)	43 (36–45)	16 (14–18)			15 (13–16)	13 (11–14)
	4	52 (50–60)			50 (48–53)	40 (37–45)	45 (40–50)	17 (16–19)			16 (15–17)	13 (12–14)
	5	53 (50–57)			52 (46–54)	40 (38–44)	45 (40–55)	17 (16–18)			17 (15–17)	13 (12–14)
	6	55 (50–58)			53 (50–57)	43 (40–48)	48 (53–55)	18 (16–18)			17 (16–18)	14 (13–15)
	7	54.5 (50–66)			54 (50–58)	46 (43–48)	49 (45–53)	17 (16–21)			17 (16–18)	15 (14–15)
	8	57 (52–60)			54 (48–58)	48 (45–52)	52 (51–60)	18 (15–19)			17 (15–18)	15 (14–17)
	9	58 (53–65)			56 (52–64)	48.5 (45–55)	56 (46–66)	18 (17–21)			18 (17–20)	15 (14–18)
	10	60 (55–65)			57 (53–62)	49 (43–58)	55 (50–60)	19 (18–20)			18 (17–20)	16 (14–18)
Index	3	49 (45–55)	46 (41–47)	40.5 (37–44)	38.5 (36–40)	34.5 (29–36)	58 (51–62)	16 (14–18)	15 (13–15)	13 (12–14)	12 (11–13)	11 (9–11)
	4	51 (48–56)	48 (44–50)	42 (41–45)	40 (37–43)	34 (33–37)	61 (58–65)	16 (15–18)	15 (14–16)	13 (13–14)	13 (12–14)	11 (11–12)
	5	50 (48–55)	49.5 (49–55)	43 (40–47)	41 (37–43)	36 (31–38)	65 (62–66)	16 (15–18)	16 (14–18)	14 (13–15)	13 (12–14)	11 (10–12)
	6	52 (50–58)	51 (48–54)	45 (43–51)	43 (41–48)	38 (36–43)	68 (60–77)	17 (16–18)	16 (15–17)	14 (14–16)	14 (13–15)	12 (11–14)
	7	54.5 (48–65)	50.5 (48–55)	47 (42–50)	43.5 (40–47)	38 (35–42)	68 (63–80)	17 (15–21)	16 (15–18)	15 (13–16)	14 (13–15)	12 (11–13)
	8	55 (48–60)	51 (50–58)	47 (44–50)	44 (39–45)	39 (37–42)	71 (63–82)	18 (15–19)	16 (15–18)	15 (14–16)	14 (12–14)	12 (12–13)
	9	58 (51–65)	56 (50–61)	50 (46–60)	45.5 (41–52)	42 (36–45)	79 (68–88)	18 (16–21)	18 (16–19)	16 (15–19)	14 (13–17)	13 (11–14)
	10	60 (55–70)	55 (51–62)	50 (46–55)	45.5 (42–50)	41.5 (37–45)	79 (72–88)	19 (17–20)	18 (16–20)	16 (15–18)	14 (13–16)	13 (12–14)
Middle	3	48 (43–50)	48 (42–50)	43 (38–45)	40 (36–40)	36 (32–38)	66 (57–69)	15 (13–16)	15 (13–16)	14 (12–14)	13 (11–13)	11 (10–12)
	4	50 (46–52)	48 (45–52)	44 (42–47)	40 (40–45)	36 (34–38)	70 (63–74)	16 (15–17)	15 (14–17)	14 (13–15)	13 (13–14)	11 (11–12)
	5	50 (46–54)	50 (44–54)	45 (42–49)	42 (38–44)	37.5 (35–40)	73 (70–79)	16 (16–17)	16 (14–17)	14 (13–16)	13 (12–14)	12 (11–13)
	6	51 (50–58)	52 (48–56)	47 (43–50)	43 (40–48)	40 (37–42)	75 (68–88)	16 (16–18)	17 (15–18)	15 (14–16)	14 (13–15)	13 (12–13)
	7	52.5 (47–65)	53.5 (47–55)	47.5 (44–55)	44.5 (40–48)	40.5 (36–44)	75.5 (66–87)	17 (15–21)	17 (15–18)	15 (14–18)	14 (13–15)	13 (11–13)
	8	54 (47–60)	53 (48–60)	48 (42–53)	45 (40–48)	41 (39–45)	80 (72–85)	17 (15–19)	17 (15–19)	15 (13–17)	14 (13–15)	13 (12–14)
	9	55.5 (51–65)	57 (50–61)	51 (44–56)	47.5 (45–50)	43 (40–48)	87 (74–100)	18 (16–21)	18 (16–19)	16 (15–18)	15 (13–16)	14 (13–15)
	10	60 (54–65)	55 (37–60)	50 (48–54)	46.5 (44–50)	44 (38–59)	87 (73–100)	19 (17–21)	18 (12–19)	16 (15–18)	15 (14–16)	14 (12–19)
Ring	3	46 (41–50)	44 (40–48)	40 (35–44)	38 (34–42)	34.5 (32–36)	61 (42–65)	15 (13–16)	14 (13–15)	13 (11–14)	12 (11–13)	11 (10–11)
	4	48 (45–50)	47 (45–50)	41 (40–45)	39 (37–42)	35 (33–38)	65 (61–74)	15 (14–16)	15 (14–16)	13 (13–14)	12 (12–13)	11 (11–12)
	5	50 (44–52)	48 (43–52)	43 (42–47)	40 (35–43)	36.5 (34–40)	70 (65–73)	16 (14–17)	15 (14–17)	14 (13–15)	13 (11–14)	12 (11–13)
	6	49 (47–54)	49 (47–52)	43 (42–45)	40 (40–43)	37 (35–41)	70 (62–85)	16 (15–17)	16 (15–17)	14 (13–14)	13 (13–14)	12 (11–13)
	7	50 (45–62)	49 (45–55)	44 (40–50)	40 (38–45)	38 (34–43)	70 (62–80)	16 (14–20)	16 (14–18)	14 (13–16)	13 (12–14)	12 (11–14)
	8	51 (46–57)	50 (48–58)	45 (40–49)	42 (39–45)	40 (38–42)	73 (67–87)	16 (15–18)	16 (15–18)	14 (13–16)	13 (12–14)	13 (12–13)
	9	55 (49–62)	52 (49–59)	46.5 (44–53)	44 (40–48)	41.5 (38–45)	80 (72–93)	18 (16–20)	17 (16–19)	15 (14–17)	14 (13–15)	13 (12–14)
	10	56.5 (50–60)	55 (50–58)	48 (45–53)	45 (40–48)	42 (38–43)	81 (70–96)	18 (16–19)	18 (16–18)	15 (13–17)	14 (13–15)	13 (12–14)
Little	3	40 (38–45)	40 (38–42)	35.5 (34–38)	35 (32–35)	28 (26–31)	46 (45–50)	13 (12–14)	13 (12–13)	11 (11–12)	11 (10–11)	9 (8–10)
	4	43 (40–47)	42 (40–44)	38 (37–42)	35 (34–40)	31 (30–34)	50 (48–67)	14 (13–15)	13 (13–14)	12 (12–13)	11 (11–13)	10 (10–11)
	5	44.5 (42–48)	43 (40–46)	40 (36–41)	38 (34–40)	33 (31–35)	53 (50–58)	14 (13–15)	14 (13–15)	13 (11–13)	12 (11–13)	11 (10–11)
	6	45 (43–49)	44 (41–47)	40 (38–43)	38 (35–40)	34 (32–36)	55 (50–63)	14 (14–16)	14 (13–15)	13 (12–14)	12 (11–13)	11 (10–11)
	7	46.5 (40–50)	45 (40–50)	40 (37–45)	38 (35–42)	35 (30–36)	55.5 (50–62)	15 (14–16)	14 (13–16)	13 (12–14)	12 (11–13)	11 (10–11)
	8	45 (41–49)	44 (40–49)	40 (35–42)	39 (35–41)	35 (33–38)	58 (50–64)	14 (13–16)	14 (13–16)	13 (11–13)	12 (11–13)	11 (11–12)
	9	49.5 (45–60)	45.5 (44–56)	44 (39–55)	40 (39–45)	38 (33–40)	63 (55–74)	16 (14–17)	14 (14–18)	14 (12–18)	13 (12–14)	12 (11–13)
	10	49.5 (46–57)	48 (44–51)	43 (40–47)	40 (38–45)	37 (35–40)	63 (55–73)	16 (13–17)	15 (14–16)	14 (13–15)	13 (12–14)	12 (11–13)

PP = proximal phalanx; PIP = proximal interphalangeal joint; MP = middle phalanx; DIP = distal interphalangeal joint; DP = distal phalanx.

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Table 3
Measured finger length and girth, and calculated diameter for girls 3–10 years of age.

Finger	Age (years)	Median (range) (mm) Girth					Length	Diameter				
		PP	PIP	MP	DIP	DP		PP	PIP	MP	DIP	DP
Thumb	3	48 (45–56)			45 (42–48)	38 (33–40)	38 (35–45)	15 (14–18)			14 (13–15)	12 (11–13)
	4	50 (40–52)			46 (38–50)	40 (32–48)	43 (38–51)	16 (13–17)			15 (12–16)	13 (10–15)
	5	51 (48–58)			48 (44–56)	40 (38–45)	45 (40–52)	16 (15–18)			15 (14–18)	13 (12–14)
	6	53 (50–57)			51 (48–55)	43 (40–48)	47 (41–58)	17 (16–18)			16 (15–18)	14 (13–15)
	7	53.5 (60–52)			52 (48–57)	43 (42–50)	50 (41–40)	17 (16–19)			17 (15–17)	14 (13–16)
	8	56 (53–59)			53 (48–55)	48 (43–50)	52 (47–55)	18 (16–19)			17 (15–18)	15 (14–16)
	9	56 (51–59)			52.5 (50–56)	45 (43–50)	56 (55–65)	18 (16–19)			17 (16–18)	14 (14–16)
	10	62 (55–68)			56 (55–61)	50 (44–55)	55 (50–58)	20 (18–22)			18 (18–19)	16 (14–17)
Index	3	48 (43–50)	45 (41–48)	40 (38–45)	37 (35–40)	32 (30–34)	56 (52–60)	15 (14–16)	14 (13–15)	13 (12–14)	12 (11–13)	10 (10–11)
	4	48 (43–52)	46 (40–48)	41 (35–44)	37 (33–42)	33 (28–37)	61 (52–68)	15 (14–17)	15 (13–15)	13 (11–14)	12 (11–13)	11 (9–12)
	5	50 (46–56)	48 (43–54)	43.5 (37–46)	40 (37–45)	34 (33–38)	63.5 (52–68)	16 (15–18)	15 (14–17)	14 (12–14)	13 (12–13)	11 (11–12)
	6	52 (45–55)	50 (46–55)	44 (41–48)	42 (38–44)	35 (32–40)	66 (61–77)	17 (14–18)	16 (15–18)	14 (13–15)	13 (12–14)	11 (10–13)
	7	53 (50–58)	51.5 (48–57)	45.5 (43–50)	43 (40–48)	38 (35–42)	71.5 (60–82)	17 (16–18)	16 (15–18)	14 (14–16)	14 (13–15)	12 (11–13)
	8	54 (50–56)	53 (50–55)	48 (44–49)	45 (40–46)	40 (38–45)	72 (68–80)	17 (16–18)	17 (15–18)	15 (14–16)	14 (13–15)	13 (12–14)
	9	53.5 (52–65)	53 (50–55)	47.5 (45–50)	43.5 (40–45)	38.5 (36–40)	80.5 (79–81)	17 (17–21)	17 (16–18)	15 (14–16)	14 (13–14)	12 (11–13)
	10	57 (55–63)	55 (52–58)	49 (47–53)	45 (43–50)	40 (35–44)	80 (70–85)	18 (18–20)	18 (17–18)	16 (15–17)	14 (14–16)	13 (11–13)
Middle	3	47 (43–50)	45 (42–50)	42 (38–44)	37 (35–40)	34 (31–36)	62 (58–66)	15 (14–16)	14 (13–16)	13 (12–14)	12 (11–13)	11 (10–11)
	4	48 (42–52)	46 (42–52)	41 (38–45)	38 (35–42)	35 (32–38)	66 (60–73)	15 (13–17)	15 (13–16)	13 (12–14)	12 (11–13)	11 (10–12)
	5	50 (45–54)	48 (45–55)	44 (42–48)	40 (38–45)	36 (35–40)	70 (63–80)	16 (14–17)	15 (14–18)	14 (13–15)	13 (12–14)	11 (11–13)
	6	50 (46–55)	49 (47–55)	45 (40–50)	43 (40–45)	38 (33–42)	74 (68–83)	16 (15–18)	16 (15–18)	14 (13–16)	14 (13–14)	12 (11–13)
	7	52.5 (48–58)	52.5 (50–57)	46.5 (43–50)	43 (40–50)	38 (37–43)	79 (65–90)	17 (15–18)	17 (16–18)	15 (13–16)	14 (13–16)	12 (11–14)
	8	52 (48–55)	53 (48–46)	48 (45–50)	45 (40–48)	42 (39–44)	81 (76–90)	17 (15–18)	17 (15–18)	15 (14–17)	14 (13–15)	13 (12–14)
	9	53 (49–60)	51.5 (43–57)	48 (45–50)	44.5 (43–47)	40 (38–42)	87 (86–92)	17 (16–19)	16 (14–18)	15 (14–16)	14 (14–15)	13 (12–13)
	10	55 (52–62)	56 (52–60)	50 (46–52)	46 (43–50)	44 (38–47)	85 (77–91)	18 (17–20)	18 (17–19)	16 (15–17)	15 (14–16)	14 (12–15)
Ring	3	45 (43–48)	42 (41–48)	40 (36–44)	37 (34–41)	32 (31–36)	60 (52–62)	14 (14–15)	13 (13–15)	13 (11–14)	12 (11–13)	10 (10–11)
	4	45 (43–50)	44 (40–45)	40 (36–41)	38 (34–39)	34 (32–38)	63 (55–68)	14 (13–16)	14 (13–14)	13 (11–14)	12 (11–12)	11 (10–12)
	5	48 (43–52)	45 (43–58)	42.5 (30–42)	38.5 (30–42)	35 (33–38)	67.5 (60–76)	15 (14–17)	14 (14–18)	14 (13–15)	12 (10–13)	11 (11–12)
	6	50 (44–55)	48 (44–53)	43 (40–48)	40 (37)	36 (34–39)	70 (63–82)	16 (14–18)	15 (14–17)	14 (13–15)	13 (12–14)	11 (11–12)
	7	50 (45–55)	49 (45–55)	43 (40–48)	40 (38–45)	37.5 (34–40)	73 (58–84)	16 (14–18)	16 (14–18)	14 (13–15)	13 (12–14)	12 (11–13)
	8	50 (48–54)	50 (48–56)	45 (43–50)	42 (39–44)	39 (38–41)	76 (69–83)	16 (15–17)	16 (15–18)	14 (13–16)	13 (12–14)	12 (12–13)
	9	52.5 (49–56)	50 (49–56)	44.5 (43–50)	42.5 (40–50)	37.5 (36–41)	84.5 (83–88)	17 (16–18)	16 (16–18)	14 (14–16)	14 (13–16)	12 (11–13)
	10	53 (50–58)	53 (50–55)	48 (43–50)	43 (40–46)	40 (35–43)	82 (73–87)	17 (16–18)	17 (16–18)	15 (14–16)	14 (13–15)	13 (11–14)
Little	3	40 (38–43)	38 (37–41)	36 (32–38)	34 (32–35)	29 (27–32)	46 (40–50)	13 (12–14)	12 (12–13)	11 (10–12)	11 (10–11)	9 (9–10)
	4	40 (38–45)	38 (37–43)	35 (32–38)	33 (30–35)	30 (27–32)	48 (43–55)	13 (12–14)	12 (12–14)	11 (10–12)	11 (10–11)	10 (9–10)
	5	43.5 (40–47)	40 (38–45)	37.5 (35–40)	35 (34–40)	30 (28–38)	51.5 (48–63)	14 (13–15)	13 (12–14)	12 (11–13)	11 (11–13)	10 (9–12)
	6	45 (40–53)	42 (38–50)	39 (35–43)	36 (33–40)	33 (28–34)	54 (47–60)	14 (13–17)	13 (12–16)	12 (11–14)	11 (11–13)	11 (9–11)
	7	45 (43–50)	44 (40–48)	40 (38–43)	38 (35–42)	33 (31–39)	57.5 (47–65)	14 (14–16)	14 (13–15)	13 (12–14)	12 (11–13)	11 (10–12)
	8	45 (42–50)	45 (42–49)	41 (38–44)	39 (36–41)	37 (32–38)	60 (51–68)	14 (13–16)	14 (13–16)	13 (12–14)	12 (11–13)	12 (10–12)
	9	45.5 (45–54)	45.5 (43–50)	40 (38–45)	38 (36–42)	34 (33–36)	65.5 (62–67)	14 (14–17)	14 (14–16)	13 (12–14)	12 (11–13)	11 (11–11)
	10	50 (45–55)	48 (45–50)	43 (40–45)	40 (38–45)	36 (33–43)	61 (55–72)	16 (14–18)	16 (14–16)	14 (13–14)	13 (12–14)	11 (11–14)

PP = proximal phalanx; PIP = proximal interphalangeal joint; MP = middle phalanx; DIP = distal interphalangeal joint; DP = distal phalanx.

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$$\tau = \frac{F}{A} = \frac{F}{0{,}25\pi D^2}$$

τ	shear force	$[\frac{N}{mm^2}]$
A	cross-sectional area of the finger	$[mm^2]$
F	applied force	$[N]$
D	diameter of the finger	$[mm]$

Fig. 2. Mathematical dependence between the diameter of the finger and shear stress in materials.

equivalent to a weight of 50 kg on a child's finger. The smaller the diameter of the finger, the greater the internal tension in the tissue and the faster the load boundary is reached at which a structural lesion can occur (Fig. 2). Finger length is also relevant with regard to power-operated window injuries because many newer motor vehicles increasingly have an oblique design of the seal entry that allows a child's short finger to be jammed over almost its entire length. Our data indicate that the little finger and the distal phalanges of all fingers are most at risk with regard to jam injuries. This study focused on the 3–10 year age group because most jam injuries happen in young children (Doraiswamy and Baig, 2000; Doraiswamy, 1999). Children under three are not in danger when child restraint systems are correctly used because of the height of the seal entry above the seat.

This study has some limitations. It is possible that the children selected in this cross-sectional investigation are only regional or national representative. Whether children aged 3–10 years of other ethnicities have similar finger dimensions is not known. Also, finger diameter is not exact because the anatomical cross-section of the finger, whether proximal or distal, is not perfectly circular. However, approximate diameter should be sufficient to estimate the risk to children's fingers in power-operated windows.

Using these data, further experimental investigation is planned in regard to both the risk and prevention of jam injuries to children's fingers in power-operated windows, and finally to determine a new boundary value for the closing force of automatic, power-operated window lifters of motor vehicles.

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