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Original Research

Normative Values for Pinch Strength—Relationship With Joint Hypermobility as Measured With the Beighton Criteria

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Purpose: This study aimed to determine normative ranges of static pinch strength as measured with a spring gauge in adults of working age and investigate whether pinch strength is associated with hand hypermobility. A secondary aim was to explore whether the Beighton criteria for hypermobility are associated with hypermobility in joints of the hand during forceful pinching.
Methods: A convenience sample of healthy men and women aged 18–65 years were recruited for measurement of lateral pinch, 2-point pinch, 3-point pinch, and joint hypermobility according to the Beighton criteria. Regression analysis was used to determine the effect of age, sex, and hypermobility on pinch strength.
Results: Two hundred and fifty men and 270 women participated in this study. Men were stronger than women at all ages. Lateral and 3-point pinch were greatest for all participants and 2-point pinch was the least strong. There were no statistically significant differences between age groups, but a trend for the lowest pinch strength to occur before the mid-thirties was seen in both sexes. Thirty-eight percent of women and 19% of men were hypermobile; however, these participants statistically insignificant differ in pinch strength compared with other participants. The Beighton criteria corresponded strongly with hypermobility in other joints of the hand as observed and photographed during pinch. Hand dominance did not show clear relationships with pinch strength.
Conclusions: Normative lateral, 2-point, and 3-point pinch strength data for adults of working age are presented with men having greatest pinch strength at all ages. The Beighton criteria for hypermobility are associated with hypermobility in other joints of the hand.
Clinical Relevance: Benign joint hypermobility is not related to pinch strength. Men have greater pinch strength at all ages than women.

Pinch strength may be measured during hand rehabilitation and neurologic assessment,[1] and is considered in designing various tools and technologies, such as adaptive switches used by people with disabilities.[2] The force that an individual can produce during hand grip is highly predictable if their age and sex are known, as normative data have been collected from several countries[1]; however, inclusion of normal participants, definition of hand dominance, instrumentation, testing protocol, and calculation of strength vary between studies. Furthermore, no Australian values are available.

The following 3 types of prehension are formed between the thumb and fingers: (1) 2-point pinch, also called pincer or pulp pinch, (2) lateral pinch, or key pinch, and (3) 3-point pinch, also called 3 jaw chuck and palmar pinch (Fig. 1).[3] The latter 2 types of pinch are considered to generate the greatest force.[2]

The ability to pinch combines motor coordination, sensory awareness, and joint integrity. The interphalangeal joint of the thumb allows flexion and extension and limits movement in other planes by the shape of the joint surfaces, collateral ligaments, and volar plate.[4] It frequently allows hyperextension and may flex to

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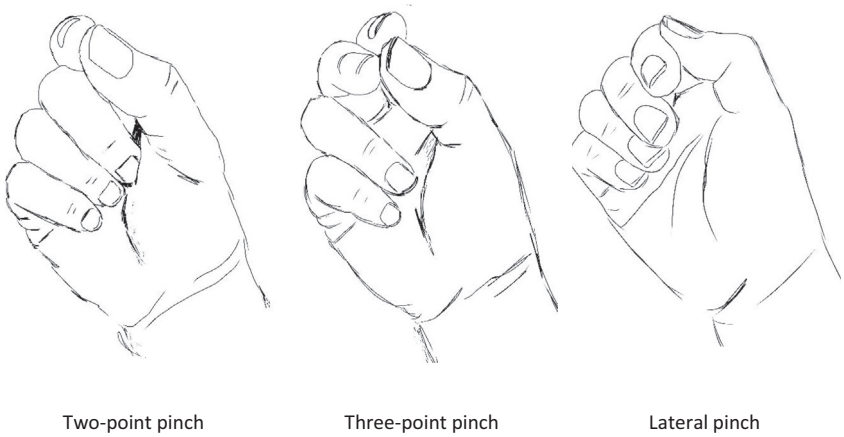


Figure 1. Nonclamenture used in this study to describe 2-point, 3-point, and lateral pinches.

Table 1
Normative Data for Three Types of Pinch Measured in the Left and Right Hands of Men and Women Participants, divided by sex and age.

Men ($n = 250$) Age, y	Two-Point Pinch (kg) Right Hand	Two-Point Pinch (kg) Left Hand	Three-Point Pinch (kg) Right Hand	Three-Point Pinch (kg) Left Hand	Lateral Pinch (kg) Right Hand	Lateral Pinch (kg) Left Hand
18–25 ($n = 98$)	5.9–6.8, $\bar{x}$6.8 (2.1)	5.6–6.4, $\bar{x}$6 (2)	8.1–9, $\bar{x}$8.5 (2.3)	7.6–8.5, $\bar{x}$8 (2.4)	9.3–10.2, $\bar{x}$9.8 (2.2)	8.9–9.8, $\bar{x}$9.4 (2.2)
26–35 ($n = 48$)	7–8.2, $\bar{x}$7.6 (2.1)	6.1–7.6, $\bar{x}$7.3 (2.3)	9.2–10.6, $\bar{x}$9.9 (2.5)	8.8–10.2, $\bar{x}$9.5 (2.5)	8.8–10.2, $\bar{x}$9.5 (2.3)	8.2–9.6, $\bar{x}$.9 (2.5)
36–45 ($n = 35$)	6.4–8, $\bar{x}$7.2 (2.4)	6.1–7.6, $\bar{x}$6.8 (2.5)	9.7–11.7, $\bar{x}$10.7 (2.8)	8.9–10.7, $\bar{x}$9.8 (2.7)	8.9–10.7, $\bar{x}$9.8 (2.7)	8.2–9.6, $\bar{x}$8.9 (2.1)
46–55 ($n = 35$)	5.9–7.7, $\bar{x}$6.8 (2.6)	5.6–7.3, $\bar{x}$6.5 (2.3)	8.8–10.7, $\bar{x}$9.8 (2.7)	8.6–10.3, $\bar{x}$9.5 (2.5)	8.8–10.8, $\bar{x}$9.8 (3)	8.8–10.6, $\bar{x}$9.7 (2.7)
56–65 ($n = 37$)	5.8–8, $\bar{x}$7 (3)	5.5–7.3, $\bar{x}$6.4 (2.6)	8.1–10.7, $\bar{x}$9.4 (3.7)	7.2–9.5, $\bar{x}$8.3 (3.3)	8.6–11, $\bar{x}$9.8 (3.5)	8–10.1, $\bar{x}$9 (3)
Women ($n = 270$) Age	Two-Point Pinch (kg) Right Hand	Two-Point Pinch (kg) Left Hand	Three-Point Pinch (kg) Right Hand	Three-Point Pinch (kg) Left Hand	Lateral Pinch (kg) Right Hand	Lateral Pinch (kg) Left Hand
18–25 ($n = 87$)	4.5–5.2, $\bar{x}$4.8 (1.7)	4.4.8, $\bar{x}$4.4 (1.7)	6.1–6.8, $\bar{x}$6.5 (1.8)	5.9–6.7, $\bar{x}$6.3 (1.8)	6.8–7.5, $\bar{x}$7.1 (1.6)	6.4–7.1, $\bar{x}$6.7 (1.6)
26–35 ($n = 52$)	4.9–5.8, $\bar{x}$5.4 (1.7)	4.2–5.2, $\bar{x}$4.7 (1.6)	6.7–7.7, $\bar{x}$7.2 (1.8)	6.3–7.2, $\bar{x}$6.8 (1.6)	6.5–7.7, $\bar{x}$7.1 (2.2)	5.8–7, $\bar{x}$6.4 (2.1)
36–45 ($n = 63$)	4.5–5.5, $\bar{x}$5.1 (1.9)	4.3–5.2, $\bar{x}$4.8 (1.8)	6.7–7.9, $\bar{x}$7.3 (2.2)	6.3–7.4, $\bar{x}$6.8 (2.2)	6.4–7.5, $\bar{x}$6.9 (2.1)	6.1–7.2, $\bar{x}$6.7 (2.1)
46–55 ($n = 35$)	4.1–5.7, $\bar{x}$4.9 (2.2)	3.5–5.2, $\bar{x}$4.3 (2.4)	5.8–7.8, $\bar{x}$6.8 (2.8)	5.5–7.2, $\bar{x}$6.4 (2.3)	6.3–7.9, $\bar{x}$7.1 (2.3)	6–7.6, $\bar{x}$6.8 (2.4)
56–65 ($n = 30$)	4.2–5.8, $\bar{x}$5 (2.2)	4.5–5.9, $\bar{x}$5.2 (1.9)	5.8–7.3, $\bar{x}$6.5 (1.9)	5.5–6.8, $\bar{x}$6.2 (1.8)	6.4–7.7, $\bar{x}$7.1 (1.8)	5.9–7.2, $\bar{x}$6.5 (1.7)

The results in kilograms are displayed in 95% confidence interval, mean (SD).

65°. The first metacarpophalangeal joint is mainly limited to 40° flexion and full extension by the collateral ligaments.[5] During forceful 2-point and 3-point pinch, a small amount of abduction is allowed when the joint is extended and the collateral ligaments relaxed. At the final stage of pinching against force, rotation at the carpometacarpal joint places the tip of the thumb in opposition with the fingers and tightens the dorsal ligaments of the joint.[5]

Joint hypermobility and generalized joint hypermobility (GJH) is believed to be present in 5% to 15% of the general population,[6] but in children, women, and African or Asian populations, GJH is present in 6% to 57% of people. Generalized joint hypermobility describes features rather than a diagnosis of greater joint range of motion in joints of the upper limbs, lower limbs, and axial skeleton, and can be found in the absence of pain or severe disability.[6–8] To be considered hypermobile, a person must exhibit excess range of motion in ≥4 of 9 areas of the body, as tested using the Beighton criteria.[8] This test is considered reliable, sensitive, and easy to administer.[6,8] The Beighton criteria assess hypermobility of the thumb and wrist, fifth metacarpophalangeal joint, elbows, knees, and joints that allow a standing person to bend forward to rest their palms on the floor figure 2 (Table 1). The test does not assess the remaining metacarpophalangeal or any interphalangeal joints of the hand, and it is unclear whether the Beighton criteria are associated with hypermobility in these joints of the hand.

Much research about hypermobility has included young children, adolescents, and young adults who are athletes. Research involving young adult populations reports lower strength in flexion and extension of the knee, shoulder, and elbow in participants with GJH, compared with age- and sex-matched controls.[9–13] Clinicians who believe that hypermobile athletes have less dynamic joint stability may prescribe strength training for their injury prevention and rehabilitation.[9,12,13] However, the same studies revealed that participants with GJH differences were equal to nonhypermobile counterparts in some aspects of strength testing.[10,11] One study compared hand strength between adult participants with and without GJH, finding no differences.[14] It remains unclear whether hypermobile people are less strong than others, and furthermore, whether strength training would prevent them from being injured.

It is logical that joint stability is one element required for generation of pinch strength, but it is unknown whether hypermobility of the hand joints is related to the amount of force that can be generated for pinch strength. This leads to the hypothesis that those with hypermobility in joints of the hand will have less pinch strength than those with nonhypermobile hands. Therefore, the aim of this prospective study is to determine whether hand pinch strength is associated with benign joint hypermobility. A secondary aim is to determine whether the Beighton criteria are associated with hypermobility in other joints of the hand, which it does not test.

Materials and Methods

Ethical committee approval for this study was granted by the University of South Australia Ethics and Compliance Committee [0000027484]. A convenience sample of adults aged 18–65 years was sought through social networks of staff and students of the university and university open day visitors. Power was calculated

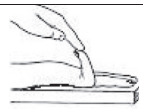
Ability to		right	left
Passively dorsiflex the fifth metacarpophalangeal joint to ≥90°		1	1
Oppose the thumb to the anterior aspect of the forearm		1	1
Hyperextend the elbow to ≥10°		1	1
Hyperextend the knee to ≥10°		1	1
Place hands flat on the floor without bending the knees		1	
		Maximum score=9	

Figure 2. Beighton criteria for hypermobility, in which participants with a score of 4 or more positive criteria are classified as hypermobile.

(0.8 power, $P < .05$) using existing 3-point pinch data of men and women. For a difference of 1.5 kg, 34 hypermobile men and 34 nonhypermobile men were required. For a difference of 1.5 kg, 23 hypermobile women and 23 nonhypermobile women were required. The standardized Nordic questionnaire was adapted for verbal screening, in which participants were asked whether they were diagnosed with upper limb or neck injuries or conditions at any time or had upper limb symptoms that caused them to seek treatment or change their activities, within the past year.[15]

Hand dominance was assessed by the Edinburgh Handedness Inventory-short form. Participants reporting that they alternated hands between tasks of writing, throwing, use of spoon, or toothbrush were classified "non-specific."[16]

Four research assistants were trained individually with a certified hand therapist (N. M.-W.) in screening participants and measuring pinch strength. Participants were positioned for pinch assessment according to the American Society of Hand Therapists' Clinical Assessment Guidelines,[1,3] using verbal instructions, such as "squeeze, harder, harder, and relax." Lateral pinch, 3—point, and 2-point pinch were assessed once each in random order to avoid any effect of fatigue.[17] Testing alternated between the right and left hands so that each hand was rested for approximately 30 seconds between measures.

All research assistants involved in data collection were trained and practiced administering and interpreting the Beighton criteria (Fig. 2).[6–8]

Beighton criteria do not include interphalangeal joints of the fingers and thumb that are involved in pinching; therefore, these joints were visually assessed as hypermobile or nonhypermobile. Goniometric assessment of each participant during pinching interfered with their natural pinching; therefore, the photographs were taken during each pinch. A certified hand therapist (N.M.-W.), who was blinded to the participants' Beighton score, considered the participant to be hypermobile if a metacarpophalangeal or interphalangeal joint of the thumb hyperextended beyond 0°, by placing a goniometer against the photograph (Fig. 2).

Statistical analysis

Statistical analysis and interpretation were prospectively designed and supervised by a statistician and re-evaluated after pinch strength data were observed to be normally distributed. Observations of normal distribution were made by creating boxplots by separating men and women and observing each type of pinch within each age group. Ninety-five percent confidence intervals (95%; significance level, >0.05) were calculated for men and women of each 10-year age group, separated by type of pinch and right and left hands.

Linear regression analysis was undertaken to quantify the effect of age and sex as these are known to be related to hand grip strength and hypermobility status on the participants' pinch strength. Each of the 3 types of pinch, separating right and left hands, were analyzed separately.

Results

Five hundred and twenty participants were included in the study; 250 men and 270 women. Forty-eight potential participants aged more than 40 years (30 women and 18 men) were excluded because they reported thumb pain or a diagnosis of arthritis of their upper limbs. As with all published studies, male sex was significantly ($P > .0001$) related to greater strength at all ages. Linear regression showed no relationship between age or hypermobility and pinch strength for men or women ($P = .33—.99$). Table 1

Figure 3. Images taken for goniometric assessment of interphalangeal joint range of motion of the thumb, index, and middle fingers.

shows mean pinch strength and confidence intervals for men and women in 10-year ranges. Age was not significantly related with 2-point, 3-point, or lateral pinch strength, (P values = .26–.95); however, there was a trend for the lowest pinch to be measured in those aged less than 35 years. Men were found to be significantly stronger in their right-hand pinch, regardless of hand dominance (Table 1).

Of the 270 women who participated, 102 (38%) scored 4 or more from 9 criteria on the Beighton test and were deemed hypermobile. Of 250 men, 47 (19%) were deemed hypermobile. Regression analysis found no significant relationship between hypermobility and any form of pinch strength for men or women ($P = .33–.64$). Therefore, the hypothesis that hypermobility of the hand is associated with reduced pinch strength is not supported.

Comparison of the Beighton criteria for assessment of hypermobility

The first 265 participants were photographed, but 53 were excluded because the photographs did not allow a perfect view of the fingers for placing a goniometer, leaving 212 participants' images for analysis. Of these, 210 (99%) participants, whose thumb, index finger, or middle finger joints demonstrated hypermobility during pinch (Fig. 3), scored more than 4 or more hypermobile criteria on the Beighton index, placing them in the hypermobile category.

Four hundred and fifty (87%) participants identified as being right handed, 65 as left handed, and 5 men reported no hand dominance (Table 2). Forty-two (17%) of 250 men were left handed, and 23 (9%) of 270 women were left handed. Two-point and lateral pinch strength in the right hand of men was significantly greater than left-handed men ($P = .002–.04$). The women showed no relationship between hand dominance and pinch strength ($P = .129–.804$).

Discussion

This study aimed to provide normative data for adult working-aged men and women and investigate any association between hypermobility and pinch strength. The findings match previous research, in which sex is related to pinch strength more than any other factor, but the relationship of pinch with age remains loosely defined. Previous normative pinch data suggests that an individual's peak pinch strength occurs in the third,[18,19] fourth,[18–22] or fifth decades,[19–22] and declines in the fifth,[18] sixth, [1,19,23] or seventh decades.[22] The present study is limited to participants aged less than 65 years, but shows no significant age range where pinch strength is greatest and only a trend toward the least strength of adults being recorded in their third decade.

Significantly greater pinch strength was found in the right hand of men in this study ($P = .002–.04$, power > 0.8), matching some previous research where adult right-hand pinch strength (measured with the same equipment and protocol) was 3% to 8 % stronger, regardless of sex or hand dominance.[1,24,25] In this study, 23 of 270 (9%) women (from all age groups) were left handed and showed no statistically significant difference ($P = .129–.804$) in strength between their right and left hands. Although a small number of them were left handed, this conclusion can be made with confidence (0.8 power, $P < .05$). The remaining research is conflicted, claiming that the dominant hand is stronger.[17,18,20,21,26–28] While other published pinch norms reveal no significant difference between right- and left-hand pinch strength.[23,28,29,30]

These findings may partly be due to hand dominance being evaluated differently between studies, and the presence of small numbers of left-handed participants in any of the studies (3% to 18% left-handedness reported), suggesting that the right hand and dominant hand are the same. It appears that prediction of pinch strength based on hand dominance is unclear.

This study found no relationship between hypermobility as assessed using the Beighton criteria and pinch strength. This finding is consistent with previous research that found no relationship between hypermobility as assessed using the Beighton criteria and grip strength.[23] Research involving shoulder, hip and knee strength reports significantly reduced strength in hypermobile individuals in some aspects of strength,[9–13] although finding them equivalent with nonhypermobile counterparts when testing other aspects of strength.[10–13] In these studies and the present study, diagnosis of GJH was made using a score of 4 or more positive Beighton criteria,[10–12] but the studies varied between protocols and equipment used to measure strength.

Application of a visual assessment (Beighton criteria) by 5 data collectors is a potential source of error in any study; however, research into the use of the Beighton criteria by trained assessors suggests good interrater reliability.[8] The finding of 99% agreement between the Beighton scores and goniometric assessment of hypermobility in this study suggests that the test does predict hypermobility in joints of the hand that it does not actually assess. Variation does exist in the interpretation of this test, some

Table 2
Three Types of Pinch (Confidence Intervals, Mean, and Standard Deviation) Divided into Left and Right Hand Dominant Participants

Men ($n = 250$) Type of Pinch	Weight of Left-Handed Men, Kg, CI, Mean (SD), $N = 42$	Weight of Right-Handed Men, Kg, CI, Mean (SD), $N = 206$	Mean Differences Between Hand Dominance	Independent Sample *t*-test Right and Left Hand, *P* value
Two-point pinch(right hand)	5.5–6.8, $\bar{x}$6.2 (2.2)	6.6–7.3, $\bar{x}$7 (2.4)	0.8221	.044
Two-point pinch (left hand)	5.6–7.2, $\bar{x}$6.4 (2.5)	6.1–6.8, $\bar{x}$6.5 (2.2)	0.1121	.768
Three-point pinch (right hand)	7.6–9.2, $\bar{x}$8.4 (2.7)	9.2–9.9, $\bar{x}$9.6 (2.7)	1.2496	.006
Three-point pinch (left hand)	7.8–9.3, $\bar{x}$8.5 (2.5)	8.4–9.1, $\bar{x}$8.8 (2.6)	0.4730	.270
Lateral (right hand)	7.9–9.3, $\bar{x}$8.6 (2.2)	9.5–10.2, $\bar{x}$9.9 (2.5)	1.3199	.002
Lateral (left hand)	7.9–9.5, $\bar{x}$8.7 (2.5)	9–9.6, $\bar{x}$9.3 (2.4)	0.7214	.076
Women ($n = 270$) Type of Pinch	Weight of Left-Handed Women, Kg, CI, Mean (SD), $N = 23$	Weight of Right-Handed Women, Kg, CI, Mean (SD), $N = 245$	Mean Differences Between Hand Dominance	Independent Sample *t*-test Right and Left Hands, *P* value
Two-point pinch(right hand)	4.3–6, $\bar{x}$5.2 (1.9)	4.7–5.2, $\bar{x}$5 (1.9)	−0.1043	.804
Two-point pinch (left hand)	4.3–6, $\bar{x}$5.3 (1.8)	4.3–4.8, $\bar{x}$4.6 (1.8)	−0.5911	.145
Three-point pinch(right hand)	5.6–7.6 , $\bar{x}$6.6 (2.3)	6.2–7, $\bar{x}$6.9 (2)	0.4049	.430
Three-point pinch (left hand)	6–7.9, $\bar{x}$7 (2.2)	6.2–7, $\bar{x}$6.9 (2.2)	−0.3387	.492
Lateral (right hand)	6.3–8.3, $\bar{x}$7.3 (2.2)	6.8–7.3, $\bar{x}$7 (1.9)	−0.2785	.578
Lateral (left hand)	6.4–8.3, $\bar{x}$7.3 (2.2)	6.3–6.8, $\bar{x}$6.6 (1.9)	−0.7559	.129

Significant differences were found between right and left hand pinch strength in men.

believing that more than 4 of the 9 criteria constitute GJH; this could be considered a limitation of this study.

Several dozen potential participants were excluded due to suspected osteoarthritis during the screening process of this study. These people described pain in joints of their wrist or hand and were excluded, although pain, stiffness, and radiologic evidence of osteoarthritis do not necessarily predict hand disability. Despite collecting data over 4 years, it was difficult to achieve high numbers of participants ages older than 45 years as many reported symptoms or diagnoses of osteoarthritis, which is an expected feature of aging in 10% to 20% of the Australian population.[30]

In conclusion, this study and previous studies found pinch strength to be most related to sex, and then, in men, the right hand, but not predicted by the age, hand dominance, or hypermobility. Although differing from some previous research regarding knee, hip, and shoulder hypermobility and strength, this study provides normative pinch data for the Australian population and reports that pinch strength is not related to hypermobility of the hand.

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