

Thumb Proprioception in Hypermobile and Non-Hypermobile Adults: An Observational Study

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Abstract

Aims and Background: Hypermobility is a common presentation in the community and is reported related to higher rates of injury and musculoskeletal pain, however the mechanism underpinning this relationship remains unclear. Poor proprioception in hypermobile joints has been proposed as a potential mechanism. This study aims to determine if there is a difference in proprioceptive acuity, as measured by joint position reproduction, in adults with generalised joint hypermobility. **Design and Methods:** A convenience sample of 26 university students and staff (mean age 29.23 years, range 18-47) were recruited, of which 12 participants displayed generalised joint hypermobility, and 14 did not. A laser light, mounted to the dominant thumb, was used to test joint position reproduction sense by pointing to targets using a unilateral active-active position reproduction protocol. **Results and Findings:** Test reliability across a range of targets was poor to good (intraclass correlation coefficients ranged from 0.1163 to 0.7256), indicating significant variability between participants. No significant differences were found in absolute angle of error between generalised joint hypermobility and non-generalised joint hypermobility participants. For direction of error in relation to the proprioceptive targets, only 30° thumb extension above horizontal was found to be significantly different between the hypermobile and non-hypermobile groups, with hypermobile participants tending to underestimate distance to target. Age and sex were not correlated to thumb proprioception. **Application and Conclusion:** The difference found in direction of error and tendency to underestimate angular distance may be protective against straying into possibly injurious end-ranges; however, larger studies are recommended to confirm this.

Keywords: proprioception, thumb, hypermobility, generalised joint hypermobility

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Introduction

Hypermobility describes the ability for joints to move beyond their normal range and can be categorised as joint hypermobility syndrome (JHS) or generalised joint hypermobility (GJH).

First described in 1967 by Kirk, Ansell and Bywaters (1967), JHS refers to the occurrence of musculoskeletal symptoms in hypermobile people without an obvious cause. Whilst the main presenting symptom is pain, JHS has also been linked to a host of systemic signs and symptoms including mitral valve prolapse, chronic fatigue syndrome, pelvic floor insufficiency, migraines, poor sleep quality and osteoporosis (Albayrak et al., 2015; Castori & Colombi, 2015; Fikree et al., 2013). GJH refers to hypermobility in the absence of musculoskeletal symptoms.

Hypermobility is commonly diagnosed through Beighton's criteria for hypermobility (Beighton et al., 1973), a simple test of eight peripheral joints and the spine. Prevalence varies widely across and within different populations, although it is generally accepted that prevalence decreases with age, is more common in females, and can be higher in Asian and African ethnicities (Hakim & Grahame, 2003). This natural variation and the paucity of high-quality epidemiological studies have hindered a true understanding of the extent of hypermobility, with reported prevalence ranging from 2-35% in males and 5-57% in females (Hakim & Grahame, 2003).

Patients presenting with musculoskeletal injuries have been found to be up to 3.35 times more likely to be hypermobile (Bin Abd Razak et al., 2014). People with JHS are more likely to report chronic, widespread pain (Mulvey et al., 2013), suffer cumulative trauma disorders from typing (Amell & Kumar, 2000), and injuries from sporting activities (Smith et al., 2005). While injury rates appear higher in those with hypermobility, it is unclear if hypermobility reflects impaired intrinsic tissue integrity, or affects the functional use of the joint, increasing the risk of secondary injury.

One possible explanation for the higher injury rates in subjects with GJH is impaired proprioception, which is generally thought to be reduced in hypermobile people (Ruemper & Watkins, 2012). Defined as the detection of joint motion and position, proprioception plays a vital role in a range of activities, from the most basic of postural control tasks through to complicated, intricate movements that require precise

coordination and grading of force (Hillier et al., 2015; Suetterlin & Sayer, 2014). It is important in preventing possibly injurious excessive end range movement (Sahin et al., 2008), with reduced proprioception and sensory feedback also implicated in reduced balance, and falls (Hall et al., 1995; Hillier et al., 2015; Parkhurst & Burnett, 1994; Proske & Gandevia, 2012; Schifftan et al., 2015).

There are few studies on proprioception in hypermobile populations with the findings inconclusive. A meta-analysis involving five primary studies (n=254) (Smith et al., 2013) concluded that those with GJH had significantly poorer lower limb joint position sense ($p < 0.001$) and threshold detection to movement ($p < 0.001$) than those without GJH, however the evidence associated with upper limb proprioception was less clear.

Proprioception in the upper limb is important due to its vital role in nearly all activities of daily living. The thumb is of particular importance in the upper limb tasks of manipulation, grasping and gripping (Ladd et al., 2013), and has been linked to osteoarthritis and injury in hypermobile subjects (Garcia-Elias & Orsolini, 2011; Wolf et al., 2011). In a study comparing GJH to non-hypermobile people, significantly reduced balance and stability was found, and reduced proprioception in the GJH participants was proposed as one possible cause (Falkerslev et al., 2013).

Due to the role of proprioception in normal joint function it is important to investigate whether hypermobility and proprioception are related. The joints of the thumb are commonly injured by traumatic dislocation or by cumulative trauma where joints are subluxed over time (Taylor et al., 2013). However, to date no studies have explored the relationship between proprioception and hypermobility in the thumb. This observational study aimed to investigate the relationship between thumb proprioception in people with GJH compared to non-hypermobile people.

Materials and Methods

This research was conducted as part of an Honours study.

Ethical approval

This study was approved by the University of South Australia Human Research Ethics Committee (approval number: 0000035999).

Participants

Healthy adult participants were recruited by convenience sampling of staff and students at the University. Exclusion criteria included: 1) pain, injury, numbness, altered sensation or weakness in the dominant arm or hand that has lasted for six months or longer, or required treatment in the six months preceding testing; 2) peripheral neuropathy; 3) diabetes and hypertension; 4) carpal tunnel syndrome; 5) Parkinson's disease, stroke or any other neurological condition likely to affect proprioception; 6) JHS or any other heritable disorder of connective tissue; 7) diagnosis of dysfunction of short-term memory; and 8) pregnancy, current or in the six months preceding testing. Participants were required to be able to read, understand and sign an informed consent form.

As proprioception is reported to decline with advancing age (Goble, 2010; Goble et al., 2009; Proske & Gandevia, 2012) the sample population was limited to adults aged 18-50 years, a range in which there is minimal expected variation in proprioception (Goble, 2010).

The Beighton scale (Beighton et al., 1973) was used to determine the degree of articular mobility, with a Beighton score of four or more used to indicate hypermobility. Testing was performed on the dominant hand, as determined with the FLANDERS Handedness survey (Nicholls et al., 2013).

Apparatus

The test apparatus was custom-made for this study (Figure 1). Participants sat comfortably on a height adjustable chair with the arm to be tested abducted between 20° to 30° to allow the forearm to rest comfortably in the forearm trough (diameter 150 mm, length 315 mm). The trough was lined with 10 mm medium density rubber and mounted on a solid wooden base. A vertical metal plate for resting the ventral aspect of the hand against to standardise hand position was located centrally at the end of the tube. This hand-plate was shaped to minimise contact with the thenar eminence, and therefore minimise extraneous cutaneous proprioceptive inputs during thumb movements (Gay et al., 2010).

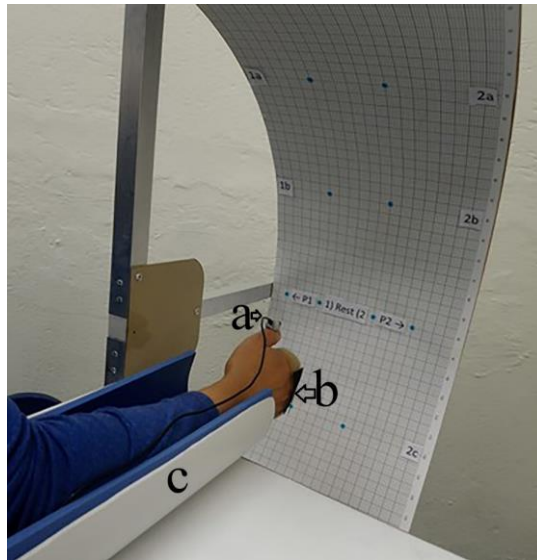


Figure 1 Experimental Apparatus showing a mounted target board and the testing position for a right-handed participant. The forearm lies within a fixed trough (c) and the hand is resting against the hand-plate (b) with laser mounted to thumb nail (a), pointing to target grid.

A semicircular screen of height: 300 mm, radius: 332 mm was mounted vertically such that the centre of the semicircle was aligned with the carpometacarpal (CMC) thumb joint when the forearm and hand are placed in the apparatus (Figure 1). The screen was of 1250 mm length, covering 207.5° from the centre of the circle.

As thumb movements are a composite of movement at all three thumb joints: the CMC, metacarpophalangeal, and interphalangeal joints. to measure movement across all joints, the CMC joint position was palpated and aligned in the horizontal plane for each participant, fixing it at the centre of the semicircle. A small laser was mounted to each participant's thumb nail with tape, and a Velcro strap placed around the dorsum of the hand over the metacarpophalangeal joints of the second to fifth digits to stabilise the hand to the hand-plate.

A target grid was attached to the surface of the semicircular screen. Markings were made at the height of the CMC joint to indicate the rest position, and a total of four targets were marked at 60° (A) and 30° (B) above the rest position, and 30° (C) and 60° (D) below the rest position. A practice target was located horizontally away from the rest position in the direction of thumb abduction. All markings were made in duplicate 4.3 cm away either side from the vertical hand-plate to allow comfortable movements of both left

and right-handed participants (right-handed participants used the targets on the left-hand side and left-handed participants used the targets on the right-hand side of the midline).

The position of the laser light on the grid was recorded by photograph during testing, and timing was carried out using a stopwatch with lap-timer function.

Protocol

The experiment involved using the thumb-mounted laser to point to four unique targets (A, B, C and D) in the vertical axis with the ventral aspect of the hand stabilised in the jig (as described above). Each target was tested twice, with the order of testing randomised. Participants removed one of 24 paper slips (containing all possible permutations of order of the four targets) from an opaque bag with the letters A, B, C and D in random order. The paper slip was returned to the bag before the participant removed another to determine the order of the second round. So that no target would be tested twice in a row, the first target in the second round was not allowed to be the last target of the first round. Targets were set at angles of 30° and 60° above and below horizontal as these angles were considered safe and representative of angles commonly encountered in manual tasks.

The timing of testing was strictly regulated as the length of time positions are held correlate with proprioceptive acuity (Suetterlin & Sayer, 2014), and rests between tests can help maintain concentration (Vafadar et al., 2016).

An ipsilateral, active positioning and active reproduction protocol was utilised. This involved using the same thumb throughout testing to actively move the laser pointer to one of the four points using visual guidance. A resting neutral position was established to allow the angular distance between targets to be regulated. The laser was moved from the rest position to the first target and held for three seconds before returning to neutral. After five seconds rest, participants were instructed to close their eyes and return as close to where they believed the target to be. The examiner photographed the position of the laser light on the grid and instructed the participant to return to the rest position. Participants were instructed not to open their eyes until back at the rest position to prevent any possible learning effect gained from knowledge of

their performance. After five seconds on the neutral rest position, the process was repeated until all four targets had been tested twice each.

The difference between the actual target angle and the achieved angle relative to the CMC joint of the thumb, the absolute angle of error (AAE), was used to gauge the participant's proprioceptive acuity.

Before testing began, participants received a verbal explanation of the purpose of testing and the protocol. They were instructed that all movements were to come from the thumb, and that the hand should be rested lightly against the hand-plate for stabilisation purposes only. Under protocol timing conditions, all participants were allowed two practices using the practice target located off to the side of thumb abduction. After position reproduction, in addition to keeping their eyes closed until back at the rest position, participants were not offered any feedback on their accuracy.

Reliability testing was conducted approximately one week after initial testing using the same procedure as described.

Data analysis

The grid coordinates of the laser pointer in relation to the targets were extracted from the photographs by a researcher blinded to participant hypermobility status and entered into Microsoft Excel 2016© (ver 1802; Microsoft; Redmond, Washington). Data was collated and transferred to MedCalc© statistical software (ver 18.5; MedCalc Software bvba; Oostende, Belgium) for analysis.

Absolute Angle of Error: The direct linear distance from the target to the reproduced position was calculated using the grid co-ordinates and Pythagorean Theorem ($X^2 + Y^2 = Z^2$). This distance was then used to calculate the AAE (the difference between the angle from the CMC to the target, and the angle from the CMC joint to the actual reproduced position) using $\tan^{-1}(\text{Opposite} / \text{Adjacent}) = \text{AAE}$, where the adjacent length was the distance from the CMC joint to the target grid (332 mm).

Direction of error (DOE): DOE refers to the orientation of the reproduced position in relation to the target position on the target surface. The formula $\tan^{-1}(X / Y) = \text{DOE}$ was used, where X and Y were the laser grid co-ordinates obtained from photographic records. DOE results were separated into non-

hypermobile and hypermobile groups, then plotted on radar graphs across eight segments of angular distance 45° centred on positions of 0°, 45°, 90°, 135°, 180°, 225°, 270° and 315°.

A P-value of 0.05 was used for statistical significance. All data was back-transformed after logarithmic transformation to account for any non-normal distributions and allow use of parametric statistics. Repeat data for the reliability subjects was analysed using intraclass correlation coefficient (ICC) statistics. To identify the effects of potential confounders such as age and gender, Pearson correlation coefficients was calculated for each variable on the AAE data. Independent sample T-tests were performed to compare hypermobile with non-hypermobile AAE and DOE.

Results

Twenty-six people (14 non-hypermobile, 12 hypermobile) volunteered for this study. Recruitment and data collection were carried out between the 6th and twenty-ninth of June 2018. One participant's data was removed due to failure to adhere to the test protocol. Characteristics of the included participants are presented in Table 1. Nine non-hypermobile participants returned for reliability testing.

Table 1 Age, Sex and Hand Dominance of the 25 Participants with and without Joint Hypermobility as assessed by the Beighton Criteria.

Group	N	Mean Age: years (range)	Sex		Dominant Hand		Mean Beighton score (range)
			Male	Female	Left	Right	
Total sample	25	28.6 (18-47)	8	17	1	24	3.2
Non-hypermobile	13	32.5 (21-47)	5	8	0	13	1.2 (0-3)
Hypermobile	12	26.8 (18-39)	3	9	1	11	5.3 (4-9)

Reliability

Correlations on repeated measures ranged from poor to good. ICCs for target (A) was poor (0.3174, 95% CI -2.9601 to 0.8538), (B) was fair (-0.4974, 95% CI -2.8265 to 0.6006), (C) was poor (0.1163, 95% CI -2.3180 to 0.7922), and (D) was good (0.7256, 95% CI -0.1081 to 0.9368).

Age and sex

Age was correlated poorly with AAE in all targets: (A) ($r^2 = -0.2743$, 95% CI -0.6040 to 0.1355, $P = 0.1845$), (B) ($r^2 = -0.3145$, 95% CI -0.6312 to 0.09207, $P = 0.1257$), (C) ($r^2 = -0.1929$, 95% CI -0.5464 to 0.2189, $P = 0.3556$), and (D) ($r^2 = 0.1035$, 95% CI -0.3040 to 0.4791, $P = 0.6224$).

Sex was poorly and non-significantly correlated with AAE in all targets: (A) ($r^2 = 0.1404$, 95% CI -0.2697 to 0.5074, $P = 0.5031$), (B) ($r^2 = 0.02469$, 95% CI -0.3741 to 0.4158, $P = 0.9067$), (C) ($r^2 = 0.2005$, 95% CI -0.2114 to 0.5519, $P = 0.3366$), and (D) ($r^2 = 0.1693$, 95% CI -0.2421 to 0.5290, $P = 0.4186$).

Hypermobile vs non-hypermobile and AAE

Targets (A), (B) and (C) failed F-Testing for equal variances hence the Welch t-test for samples of unequal variances was applied. All targets failed to reach significance; (A) (DF22.4, $t = -0.536$, $P = 0.5976$), (B) (DF20.3, $t = 0.724$, $P = 0.4777$) and (C) (DF21.4, $t = 0.905$, $P = 0.3755$). Target (D) displayed equal variances using the F-test for equal variances ($P = .008$), but failed to reach significance on the t-test for samples of equal variances (DF23, $t = 0.920$, $P = 0.3669$)

Hypermobile vs Non-Hypermobile and DOE

Targets (A) and (C) failed F-Testing for equal variances hence the Welch t-test for samples of unequal variance was applied. Both targets failed to reach statistical significance; (A) (DF47.6, $t = -1.346$, $P = 0.1847$), and (C) (DF45.1, $t = 0.320$, $P = 0.7507$). Targets (B) and (D) both displayed equal variances using the F-test for equal variances ($P < 0.001$), so the independent sample t-test for samples of equal variances was applied. Target (B) (DF48, $t = -2.854$, $P = 0.0063$) was found to be significantly different between hypermobile and non-hypermobile subjects, while (D) was not (DF48, $t = -0.990$, $P = 0.3271$).

The graphical representation of DOE with the size of AAE and distribution of errors over eight 45° segments for non-hypermobile and hypermobile participants is shown in Figure 2. The single left-handed

participant's results were mirrored on the vertical axis to account for any influence handedness and the hand-plate may have had.

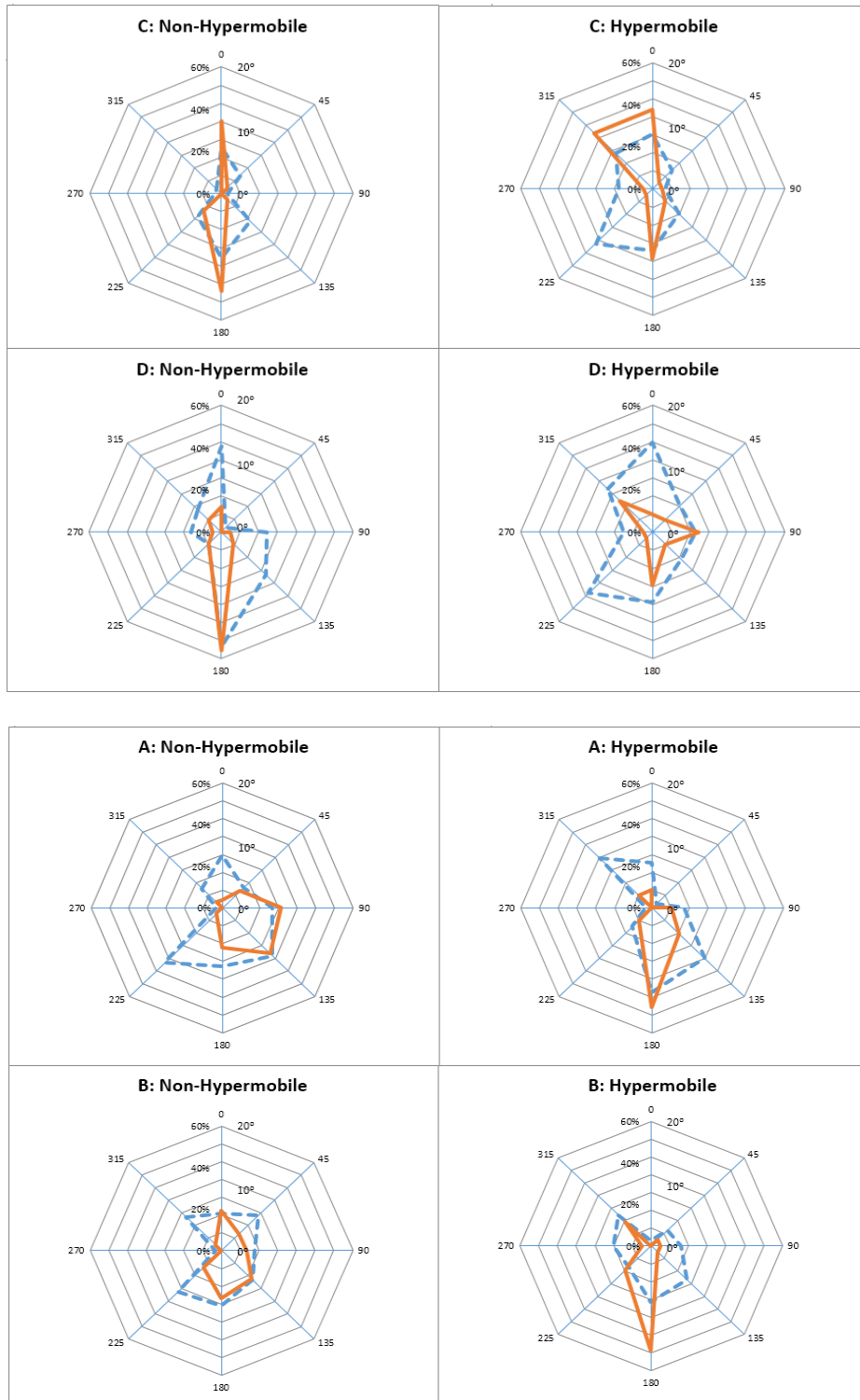


Figure 2 Graphical representation of direction of error with the size of the absolute angle of error and distribution of errors over eight 45° segments for non-hypermobile and hypermobile participants. The dashed line indicates size and the solid line indicates distribution of errors across the eight 45° segments for each target in the hypermobile and non-hypermobile groups.

Discussion

Reduced proprioception has been correlated with increased injury rates (Bin Abd Razak et al., 2014) while reduced proprioception has been observed in some joints of people with GJH and JHS when compared to non-hypermobility people (Smith et al., 2013). Due to the importance of the thumb joints in tasks of daily living, the frequency of thumb joint disorders and prevalence of asymptomatic GJH, this study aimed to determine if a relationship of reduced proprioception exists in the dominant thumbs of people with GJH. Results of this study suggest that in the thumb, there is no difference in proprioception between asymptomatic adults with and without GJH. Due to the unique characteristics of the thumb in relation to other joints, it is unlikely these results can be generalised to other joints.

Reliability testing for non-hypermobility participants was poor to good, suggesting variability in performance in repeated measures. In this study participants were not given any indication of their performance, so no learning effect between testing and retesting would be expected which may account for this variability.

Thumb movements occur in two axes and are the result of a synthesis of movement at three joints. As such, despite the proprioceptive acuity demanded of the thumb in fine motor tasks, it is likely that a moderate amount of variation at each of the three joints is a common occurrence which may also give rise to greater overall variation.

During testing, several participants initially had difficulty pointing the laser to target (D). Many participants appeared unaccustomed to moving the thumb, most notably the distal interphalangeal joint, into the higher degree of flexion required to reach the target. This was more apparent in the non-hypermobility subjects, possibly due to a reduced overall range of motion. Further, this movement into flexion downward and parallel to the palm may be a movement not normally performed in functional activities. For future studies, a more functional movement, such as moving from thumb extension to flexion or opposition might be more meaningful and familiar to participants.

Both age and sex were dismissed as confounders as analysis found no correlation with AAE. No correlation was found between hypermobility status and AAE in any of the four targets; however, analysis

of DOE and hypermobility status found a significant difference at target (B), 30° into thumb extension above horizontal. Looking at the graphical representation of the size (AAE) and distribution (DOE) of errors suggests that hypermobile participants were more frequently underestimating the distance to target (B). Though not reaching significance, this pattern was repeated in targets (A) and (C). This tendency to fall short of targets could be a protective mechanism to avoid possibly injurious end-ranges.

Due to the ligamentous laxity seen in hypermobile people, the authors had hypothesised that deficiencies might be more likely to occur in the outer ranges of joint motion, as the outer ranges rely more heavily on contributions from ligaments and the joint capsule than the mid-ranges, in which muscle afferents play a larger role (Myers & Lephart 2000). One possible explanation for no significant difference in the outer ranges (targets [A] and [D]), is a compensation through reweighting of non-ligament afferent sensory signals in the central nervous system. The reported increased rate of musculoskeletal injuries in hypermobile people may therefore be due to an issue such as structural integrity, rather than a functional issue such as proprioception.

Due to the small sample size, the results of this study are prone to the influence of other possible confounding factors. For example, highly trained athletes (Muaidi et al., 2009) and musicians (Artigues-Cano & Bird, 2014) have been strongly correlated with increased proprioceptive acuity. Other factors, such as touch-typing ability, arguably now a much more common and practised skill due to the ubiquity of computer use, may influence proprioceptive acuity. This is an area which future, larger studies should address when comparing hypermobile and non-hypermobile people.

Conclusion

Age and sex were found to not influence joint position reproduction. No relation was found between hypermobility status and AAE and DOE for three of the four targets in the dominant thumb of the hypermobile and non-hypermobile participants in this study. Only DOE for target (B), 30° thumb extension above horizontal, showed a significant difference between hypermobile and non-hypermobile participants.

Non-hypermobility participants tended to underestimate the distance of movements at 30° thumb extension above horizontal, which may be protective against allowing joints to move into injurious ranges.

Future studies should build on this study by using larger sample sizes and controlling for populations which may display exceptionally good or poor proprioceptive ability in adults. Research should investigate differences between inner and outer ranges of joint motion and the development of tools to allow the clinician to efficiently and cost-effectively identify deficits in proprioception.

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Conflict of interest

The authors declare there are no perceived conflicts of interest

Ethics approval

This study was approved by the University of South Australia Human Research Ethics Committee (approval number: 0000035999).

Key Points for Occupational Therapy

- Age and sex were found to not influence joint position reproduction.
- Non-hypermobile participants tended to underestimate the distance of movements at 30° thumb extension above horizontal, which may be protective against allowing joints to move into injurious ranges.
- Hypermobility status was not consistently related to joint position reproduction
- Any increased rate of musculoskeletal injuries in hypermobile people may therefore be due to an issue such as structural integrity, rather than a functional issue such as proprioception.

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