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RESEARCH

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No significant links between somatognosia, stereognosia, and hypermobility: sensory processing unlikely to drive common complaints in hypermobile population

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Abstract

Background Previous research has demonstrated impaired proprioception and poorer responses to tactile deep pressure, visual-tactile integration, and vestibular stimuli in individuals with generalized hypermobility, potentially leading to sensory processing issues. Therefore, we aimed to explore the influence of hypermobility on somatognosia and stereognosia.

Methods Forty-six participants were assessed using the Beighton score and categorized into three groups: non-hypermobile ($n = 20$), symptomatic hypermobile ($n = 13$), and asymptomatic hypermobile ($n = 13$). Somatognosia was evaluated using the shoulder width test in the vertical plane and pelvic width test in the vertical and horizontal planes. Stereognosia was assessed with Petrie's test. Spearman's rank correlation coefficient was examined the relationship between the Beighton score and measures of somatognosia and stereognosia. An unpaired t-test was used to compare variables between hypermobile (both symptomatic and asymptomatic) and non-hypermobile individuals, while a one-way ANOVA was used to compare data between the three groups.

Results No significant relationship was observed between Beighton scores and measures of somatognosia and stereognosia. The t-test revealed no statistically significant differences between hypermobile and non-hypermobile groups in the shoulder width, two pelvic widths, and Petrie's tests (all $p \geq 0.105$). Similarly, one-way ANOVA showed no statistically significant differences between the three groups across these tests (all $p \geq 0.177$).

Conclusions The results indicate that somatognosia and stereognosia are not significantly related to the Beighton score and do not significantly differ between the groups studied. These sensory processing functions are unlikely to contribute to the common complaints reported by hypermobile individuals.

Clinical trial number Not applicable.

Keywords Beighton score, Asymptomatic hypermobility, Symptomatic hypermobility, Petrie test, Sensory processing

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Introduction

Hypermobility is the ability of joints to move beyond their physiological ranges of motion [1]. The prevalence of hypermobility documented in the literature varies significantly, ranging from 2 to 57% in the adult population [2–4]. This variability is primarily attributed to factors such as sex (more prevalent in females), age (more prevalent in young), and ethnicity [5, 6] along with inconsistencies in diagnostic tests and criteria due to hypermobility's diverse etiology [7, 8].

Hypermobility can manifest as localized (affecting a single joint) or generalized (impacting multiple joints, often more than five), congenital or acquired, and it may be asymptomatic or associated with various symptoms. The diverse etiology and coexistence of hypermobility with other syndromes and diseases have resulted in multiple names (e.g., hypermobile syndrome, hypermobile spectrum disorder, benign joint hypermobile syndrome), making orientation in the topic challenging [1, 9]. Consequently, a new classification was proposed to achieve consistency in terminology for hypermobility [1].

The novel classification categorizes hypermobility into three groups [1]: asymptomatic joint hypermobility, hypermobility associated with well-defined syndromes, and symptomatic joint hypermobility. Asymptomatic hypermobility includes individuals with an excessive joint range, but without associated symptoms (e.g., pain, fatigue). The second group encompasses syndromes such as Ehlers-Danlos syndrome, Marfan syndrome, osteogenesis imperfecta, and Loeys-Dietz syndrome, diagnosed based on specific criteria. Symptomatic hypermobility bridges the gap between the first and second classifications, representing hypermobile individuals with symptoms related to joint hypermobility, but not meeting diagnostic criteria for specific syndromes in the second group. Studies have identified distinct differences between symptomatic and asymptomatic hypermobile individuals, including variations in corticospinal excitability, range of motion, and physiological markers, suggesting that symptomatic individuals may experience more pronounced effects of hypermobility [10, 11]. However, most research does not differentiate hypermobile populations based on this classification system [1], raising questions about whether their findings are generalizable across these groups.

Sensory processing is a term that describes how the nervous system receives, organizes, and interprets sensory information, gathered from diverse receptors, including visual, tactile, proprioceptive, and vestibular receptors [12]. Research in hypermobile children has indicated poorer responses to tactile deep pressure, visual-tactile integration, and vestibular stimuli compared to non-hypermobile children [13, 14], suggesting broader sensory processing challenges in this population.

Sensory processing encompasses a wide range of functions, for instance, it enables the recognition of the body schema (somatognosia) and enhances the ability to recognize objects through touch (stereognosia) [12, 15]. Impaired somatognosia may affect the awareness and perception of one's body parts, including their size, volume, and spatial relationships. This impairment can lead to difficulties in controlling body movement and position. Consequently, individuals may inadvertently place their joints in vulnerable positions during activities of daily living or physical exertion, increasing the risk of joint sprains, strains, dislocations, ligament and muscle tears, meniscus injuries, overuse injuries and early onset osteoarthritis — complaints that are commonly reported in the hypermobile population [16, 17]. Similarly, impaired stereognosia can negatively impact the ability to manipulate objects effectively, especially in situations requiring fine motor skills and tactile discrimination. A systematic review [18] demonstrated that impairments in tactile discrimination, proprioception, and stereognosia are closely linked to motor functions, including manual ability, grip strength, postural control, and locomotion [10, 11, 16, 17, 19, 20]. Studies have shown that the hypermobile population tends to perform worse in these areas. Therefore, among the various sensory processing functions, somatognosia and stereognosia may be particularly important as they could contribute to the increased injury risk and musculoskeletal complaints commonly observed in hypermobile individuals.

Additionally, somatognosia and stereognosia are higher-order sensory processing functions that depend on proprioception, which provides continuous feedback about body shape, position, movement, and muscle force [21], playing a crucial role in motor skill execution and injury risk mitigation [22]. According to studies, hypermobile individuals demonstrate decreased proprioception compared to non-hypermobile individuals [23, 24]. Despite the role of somatognosia and stereognosia in motor control and injury prevention, no studies have specifically examined these sensory functions in hypermobile populations. Existing research has focused on proprioception deficits [23, 24], with inconsistent findings, and studies exploring somatognosia and stereognosia are limited to children [13, 14] or neurological disorders [18]. This highlights a critical gap in understanding their role in hypermobile population, which may inform the development of targeted preventive interventions aimed at improving body awareness and sensory processing in hypermobile individuals. Such interventions could include body awareness techniques like the Feldenkrais Method, the Alexander Technique, Tai Chi as well as sensory integration games, exercises performed without visual input, and fine motor coordination tasks to enhance somatognosia and stereognosia, ultimately reducing injury risk and musculoskeletal complaints in hypermobile population.

Therefore, we aimed to investigate relationship between hypermobility and the sensory processing abilities of somatognosia and stereognosia. Furthermore, we aimed to compare somatognosia and stereognosia between non-hypermobile and hypermobile participants, as well as between non-hypermobile participants, participants with asymptomatic generalized hypermobility, and participants with symptomatic generalized hypermobility. We hypothesized that hypermobile participants would exhibit decreased abilities in these sensory processing abilities compared to non-hypermobile participants, and individuals with symptoms would exhibit poorer abilities than those with asymptomatic hypermobility or without hypermobility.

Materials and methods

Participants

Given that no published data exist regarding the association between Beighton scores and sensory processing functions, we calculated sample size requirements based on the ability to detect a correlation of moderate magnitude (i.e., $\rho = 0.40$) [25]. The calculation was performed using G*Power version 3.1.9.7 [26] from standard two-tailed hypothesis equations using an 80% ($\beta = 0.20$) and 5% significance level ($\alpha = 0.05$) we required 44 participants to detect a moderate correlation.

Forty-six participants aged 20 to 39 years were included in the study. This age range was selected based on hypermobility thresholds defined by Singh et al. [27] and to ensure participants were assessed after growth completion but before the typical onset of degenerative conditions like osteoarthritis [28], minimizing the likelihood that symptoms were related to degenerative processes. Additionally, individuals needed to be free from serious injuries and surgeries within the past year, diagnosed medical conditions associated with motoric and sensory deficits, diagnosed symptomatic osteoarthritis, pain during testing, and pregnancy. Only non-hypermobile, asymptomatic hypermobile (no joint pain or joint pain lasting < 3 months [29]), or symptomatic hypermobile (pain of two or more joints, non-specific back pain ≥ 3 months, or joint pain lasting ≥ 3 months [29]) were eligible. Therefore, participants with known diagnosis of medical syndromes associated with joint hypermobility (e.g., Ehlers Danlos syndrome and Marfan syndrome) were excluded due to their multifactorial pathology, where multiple systemic factors could contribute to symptoms, potentially confounding the results and limiting the homogeneity of the sample. Sex-and-age specific cut off Beighton scores [27] were used to define presence (females ≥ 5 points and males ≥ 4 points) or absence of generalized hypermobility.

The study protocol was approved Ethics Committee of the Faculty of Physical Culture, Palacký University (reference number: 97/2021) and adhered to the Declaration of Helsinki. All participants signed a written informed consent document.

Procedure

All tests were conducted by experienced female physiotherapist within one session in consistent order with participants in underwear and barefoot. The tests were simple and time-efficient, with the entire session lasting no more than 30 min, minimizing the risk of fatigue or learning effects.

Beighton score

The Beighton score is a valid and reliable criterion used in diagnosing generalized joint hypermobility [2, 9]. Experienced physiotherapist employed standardized protocols using a hand-held goniometer [30] to assess the Beighton scores of participants. The assessment encompassed five components: (1) passive dorsiflexion and hyperextension of the fifth metacarpal joints beyond 90°, (2) passive apposition of the thumbs to the flexor aspects of the forearms, (3) passive hyperextension of the elbows beyond 10°, (4) passive hyperextension of the knees beyond 10°, and (5) active forward flexion of the trunk with fully extended knees, allowing the palms to rest flat on the floor [31]. It is noteworthy that the first four elements can be assigned a maximum score of 2 points each, as they are performed bilaterally (i.e., 1 point for each hypermobile joint), while the last element has a maximum score of 1 point. Consequently, the Beighton score ranges from 0 to 9 points. As stated in the *2.1 Participants* section, sex-and-age specific cut off Beighton scores were used to define hypermobility (females ≥ 5 points and males ≥ 4 points).

Somatognosia

For testing somatognosia, we employed the shoulder width test in the vertical plane and the pelvic width test in both the vertical and horizontal planes, following methods similar to Tapajcikova et al. [15]. Before the test, we adjusted the participant's stance to ensure their feet were positioned shoulder-width apart. The examiner also demonstrated the tasks to ensure that participants understood the instructions. Additionally, we measured the actual pelvis width between the anterior superior iliac spines using a pelvimeter and the shoulder width between the greater tubercles of the humerus using a measuring tape. These measurements provided the participant with an understanding of the desired shoulder and pelvis width for testing.

Participants were blindfolded during somatognosia assessment. To measure shoulder width in the vertical

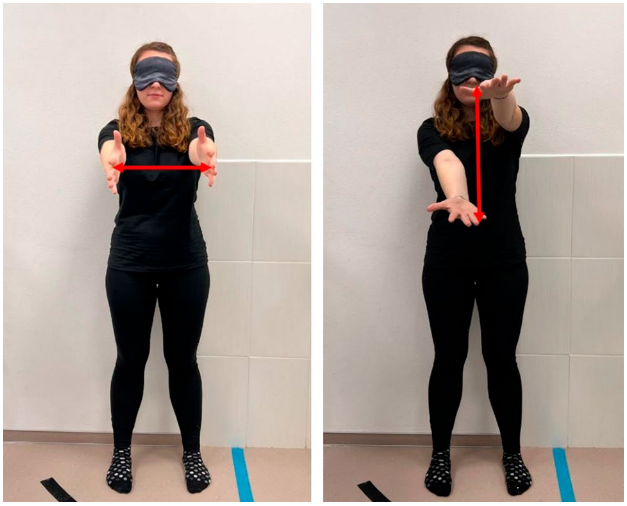

Fig. 1 Somatognosia tests. Pelvis width in the horizontal plane (left) and pelvis/shoulder width in the vertical plane (right)

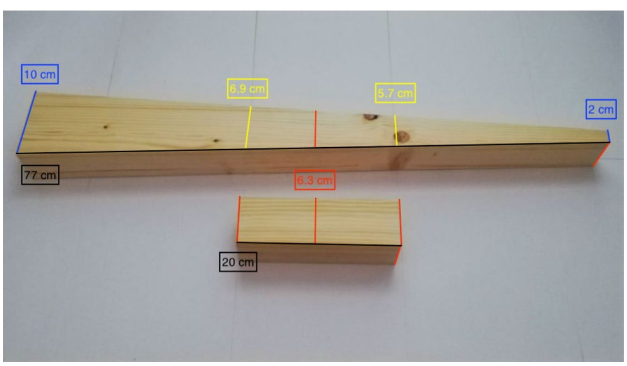

Fig. 2 Wooden blocks for Petrie test

plane, participants were instructed to raise their dominant arm above the non-dominant arm, lifting them to shoulder level and then indicate the estimated width of their shoulders (Fig. 1), ensuring that their arms remained parallel avoiding a mere shift from the horizontal to the vertical plane. The same procedure was repeated for bispinous pelvic width in the vertical plane (Fig. 1). For pelvis width in the horizontal plane, participants were required to connect their arms with palms together at shoulder height and then estimate their pelvis width (Fig. 1). Between individual tests, participants consistently returned their hands alongside their body. The difference between the actual and the estimated widths was taken for statistical analysis.

Petrie test

The Petrie test was employed for stereognosia assessment. This test has been shown to be reliable [32, 33]. The participant, positioned in front of a table, encountered two wooden blocks. The smaller block measured 6.3 cm in width, while the larger block tapered from 10 cm to 2 cm (Fig. 2). Following the explanation of test instructions, the participant was blindfolded. Using their dominant hand and exclusively their thumb and index finger, participants had 30 s to palpate the small block and memorize its width. After this period, the participant released their hand, placing it on their thigh. The small block was then replaced with the larger tapered block, positioned with the wider end on the left and the narrower end on the right from the participant's viewpoint. Once again using their dominant hand and their thumb and index finger, participants needed to identify the width corresponding to the small block. Once confident in their estimate, the participant maintained their finger placement, and the examiner employed a ruler to measure the estimated width. To enhance reliability and reduce the impact of transient factors such as stress or distractions, the process was repeated three times for the tapered block assessment (i.e., one 30 s attempt for the small block palpation, three attempts to estimate the width of the tapered block). Between each attempt, the participant had to release their hand and place it on their thigh. The mean value of the difference from the small block (6.3 cm) was subjected to statistical analysis.

Statistical analyses

The normality of the data was evaluated using a Shapiro-Wilk test and homogeneity of variance using Leven's tests. Mean ± standard deviation or median and interquartile range were calculated to describe variables based on variable type. To investigate the relationship between Beighton scores and variables, Spearman's rank correlation coefficient (ρ) was calculated. The following thresholds were used to interpret the magnitude of ρ: weak 0.00–0.39, moderate 0.40–0.69, strong 0.70–0.99, and perfect 1 [25].

Independent t-tests with equal variance or Mann–Whitney U tests were used to investigate differences in demographic characteristic and explored variables between non-hypermobile and all hypermobile groups. One-way analysis of variance with Tukey multiple comparison of means or Kruskal–Wallis tests with Benjamini-Hochberg multiple comparison of means were carried out to investigate differences in these metrics between non-hypermobile, asymptomatic hypermobile, and symptomatic hypermobile groups. Mean differences and 95% confidence intervals [lower, upper] in explored variables between subgroups and corresponding effect sizes (Hedge's g or eta squared statistic η^2) with 95% confidence intervals were calculated. The following thresholds were used to interpret the magnitude of Hedge's g: trivial < 0.20, weak 0.20–0.49, moderate 0.50–0.79, large > 0.80 effect, and the magnitude of η^2: trivial < 0.010, small 0.010–0.059, moderate 0.060–0.139, and large > 0.140 effect [34].

Table 1 Characteristic of participants

	Total (*n* = 46)	Non-hypermobile (*n* = 20)	All hypermobile[a] (*n* = 26)	Asymptomatic hypermobile[b] (*n* = 13)	Symptomatic hypermobile[c] (*n* = 13)
Age (y)	24.17 ± 3.90	24.45 ± 4.16	23.96 ± 3.76	23.62 ± 2.63	24.31 ± 4.71
Height (cm)	171.24 ± 8.44	172.75 ± 9.76	170.08 ± 7.26	170.77 ± 9.35	169.38 ± 4.63
Mass (kg)	68.95 ± 15.03	71.88 ± 19.90	66.70 ± 9.68	66.02 ± 11.11	67.38 ± 8.41
BMI (kg/m^2)	23.34 ± 3.52	23.70 ± 4.16	23.06 ± 2.99	22.58 ± 2.71	23.54 ± 3.30
Beighton (point)	5 (4)	2 (1.25) *‡	6 (2) *	6 (1) ‡	6 (2) ‡

Notes. Values are mean ± standard deviation and median (interquartile range). n: number of participants; BMI: body mass index

[a]Participants with the Beighton score exceeding the generalized hypermobility thresholds reported by Singh et al. (2017) that include [b]hypermobile individuals without symptoms and [c]hypermobile individuals with symptoms related to hypermobility

*Significant differences between non-hypermobile and all hypermobile groups according to Mann-Whitney U test ($p < 0.001$)

‡Significant differences between non-hypermobile, asymptomatic hypermobile and symptomatic hypermobile groups according to Kruskal-Wallis. Pairwise comparisons, with Benjamini & Hochberg corrections, revealed significant differences between non-hypermobile and asymptomatic hypermobile, as well as non-hypermobile and symptomatic hypermobile groups ($p < 0.001$)

Table 2 Comparison of the variables between non-hypermobile and all hypermobile groups

Variables (cm)	Non-hypermobile (*n* = 20)	All hypermobile[a] (*n* = 26)	Mean difference [95% CI]	*p*-value*	Hedge's g [95% CI]
Shoulder width	1.28 ± 10.87	2.57 ± 6.91	-1.29 [-6.59 to 4.01]	0.626	0.14 [-0.43 to 0.72]
Pelvis width in HP	-3.67 ± 7.63	-5.34 ± 7.71	1.67 [-2.94 to 6.26]	0.472	0.21 [-0.36 to 0.79]
Pelvis width in VP	-7.55 ± 6.78	-8.41 ± 7.87	0.86 [-3.58 to 5.31]	0.698	0.11 [-0.46 to 0.69]
Petrie test	0.68 ± 0.62	0.39 ± 0.58	0.29 [-0.06 to 0.65]	0.105	0.48 [-0.10 to 1.06]

Notes. HP: horizontal plane; VP: vertical plane; CI: confidence interval

[a]Participants with the Beighton score exceeding the generalized hypermobility thresholds reported by Singh et al. (2017)

*p-value according to the t-test with equal variance

Table 3 Comparison of the variables between non-hypermobile, asymptomatic hypermobile, and symptomatic hypermobile groups

Variables (cm)	Non-hypermobile (*n* = 20)	Asymptomatic hypermobile[a] (*n* = 13)	Symptomatic hypermoible[b] (*n* = 13)	F-value*	*p*-value*	η^2 [95% CI]
Shoulder width	1.28 ± 10.89	2.83 ± 4.97	2.31 ± 8.64	0.129	0.880	0.00 [0.00 to 1.00]
Pelvis width in HP	-3.69 ± 7.64	-6.28 ± 8.01	-4.40 ± 7.55	0.453	0.639	0.02 [0.00 to 1.00]
Pelvis width in VP	-7.55 ± 6.78	-8.65 ± 8.32	-8.17 ± 7.72	0.088	0.916	0.00 [0.00 to 1.00]
Petrie test	0.68 ± 0.62	0.49 ± 0.66	0.28 ± 0.49	1.801	0.177	0.08 [0.00 to 1.00]

Notes. HP: horizontal plane; VP: vertical plane; CI: confidence interval

[a]Participants with the Beighton score exceeding the generalized hypermobility thresholds reported by Singh et al. (2017) without symptoms associated with hypermobility

[b]Participants with the Beighton score exceeding the generalized hypermobility thresholds reported by Singh et al. (2017) with symptoms associated with hypermobility

*F-value$_{(2, 43)}$ and p-value according to the one-way analysis of variance

Statistically significant level was set at $\alpha = 0.05$ for all analyses. The statistics were computed using Microsoft® Excel® for Office 365 MSO and RStudio® version 2023.09.02. Data from all 46 participants were analyzed (i.e., no missing data).

Results

A sample of 46 individuals participated in the study, and data from all participants were analyzed (Table 1). The sample included 37 females (15 non-hypermobile, 11 asymptomatic hypermobile, and 11 symptomatic hypermobile) and 9 males (5 non-hypermobile, 2 asymptomatic hypermobile, and 2 symptomatic hypermobile). No significant differences were identified in participants' characteristics except of differences in Beighton scores. Differences in Beighton scores were significant between non-hypermobile and all hypermobile, asymptomatic hypermobile, and symptomatic hypermobile groups (all $p < 0.001$), but not statistically significant between asymptomatic and symptomatic hypermobile ($p = 0.920$).

Spearman's correlation did not reveal any statistically significant relationship between Beighton score and shoulder width ($\rho = 0.11$; $p = 0.408$), pelvis width in the horizontal ($\rho = 0.07$; $p = 0.596$) or vertical ($\rho = 0.13$; $p = 0.333$) planes, and Petrie test (ρ = -0.12; $p = 0.402$). No significant differences were identified between non-hypermobile and all hypermobile groups (Table 2), or between non-hypermobile, asymptomatic hypermobile, and symptomatic hypermobile groups (Table 3) in these measures.

Discussion

The purpose of this research was to investigate the relationship between Beighton score, somatognosia, and stereognosia, and to compare somatognosia and stereognosia between non-hypermobile and hypermobile groups, as well as between non-hypermobile, asymptomatic hypermobile, and symptomatic hypermobile individuals. In our cohort, no significant correlations were found, and there were no differences in somatognosia and stereognosia measures between any of the explored groups. These results indicate that somatognosia and stereognosia are not associated with hypermobility, suggesting that they likely do not contribute to the pain, musculoskeletal issues, and other complaints reported by hypermobile individuals.

Sensory information from the visual, tactile, proprioceptive, and vestibular systems, and its integration and processing in various central nervous system regions, creates a sensory "image" of one's body, which is necessary to effectively plan and control all movements and decrease the risk of musculoskeletal of injuries [35]. Hypermobile individuals demonstrate decreased proprioception [23, 24], as well as poorer responses to tactile deep pressure, visual-tactile integration, and vestibular stimuli compared to non-hypermobile individuals [13, 14]. Therefore, we hypothesized that somatognosia would be worse in hypermobile compared to non-hypermobile individuals. However, there were no statistically significant differences between the groups.

To our knowledge, no studies have explored somatognosia (awareness of the relationship between body parts) in the hypermobile population; however, several studies have investigated body awareness. Body awareness is a broader term that refers to the perception of one's body in space (proprioception) and internal bodily sensations (interoception), as well as how these are interpreted in relation to mental processes like thoughts and emotions. Research using the Porges Body Perception Questionnaire for body awareness showed that hypermobile individuals exhibit enhanced interoceptive sensitivity, indicating a more finely tuned sensory representation of internal bodily signals [36]. However, it should be noted that in this particular study, all participants with a Beighton score of 1 or more were classified as hypermobile. In contrast, studies that applied the same hypermobility thresholds as our study (> 4 for males and > 5 for females) found no significant differences in body awareness between hypermobile and non-hypermobile participants based on self-reported questionnaires [37, 38], which aligns with our findings using quantitative measures of somatognosia.

Somatognosia can be trained and improved, as evidenced by several studies showing that athletes have better somatognosia than the general population. Such training and improvements may be beneficial to certain populations. For instance, it was shown that integrating body awareness into sport training helped reduce musculoskeletal painful syndromes in cross-country skiers [39]. Additionally, karate athletes demonstrated better somatognosia compared to a healthy population not engaging in regular sports [15]. These athletes exhibited a superior ability to estimate their body dimensions, such as the width of their fists and shoulders, indicating a heightened ability to feel and "read" their bodies [15]. Meditation practice also enhances the ability to monitor and optimize necessary adjustments in a person's movement trajectory, resulting in improved motor performance [40]. Based on the results of this study and other research, it remains uncertain whether body awareness training would be more beneficial for the hypermobile population compared to the non-hypermobile population. While it may still improve body awareness and potentially reduce musculoskeletal pain if present, its necessity for hypermobile individuals is not definitively established.

Among the motor characteristics commonly observed in patients with hypermobility is clumsiness [41]. Additionally, individuals with connective tissue disorders exhibit hand fine motor function impairment [19, 20], which is associated with poorer stereognosis (ability to recognize objects through touch) [42]. Therefore, we hypothesized that hypermobile individuals would have poorer stereognosis compared to a non-hypermobile group. To assess stereognosis, the Petrie test was employed. Estimating width through tactile perception without visual stimuli is a challenging task. Due to its difficulty, the Petrie test may be sensitive enough to recognize small differences in the quality of stereognosis. However, the difference in Petrie scores between groups were not statistically significant.

Surprisingly, the participants in our study were more accurate in the Petrie test (0.54 ± 0.6 cm) compared to karate athletes (1.90 ± 3.48 cm) and the general population (2.94 ± 6.19 cm) studied by Tapajcikova et al. (2022). This discrepancy may be attributed to methodological differences: Tapajcikova et al. (2022) allowed only one trial, whereas our study averaged three attempts to estimate the width of the large block.

Based on the width identified by participants that they perceived as corresponding to the small block width during the Petrie test, the population can be categorized into three groups using the following thresholds: 5.7–6.9 cm classified as normal evaluators, ≤ 5.7 cm as reducers, and ≥ 6.9 cm as augmenters [43]. Studies suggest augmenters are more sensitive to environmental stimuli like white noise, pain, and loud music compared to reducers [44, 45]. Reducers may seek more environmental stimulation to compensate for reduced sensory experiences, while augmenters may prefer less stimulation and avoid highly stimulating situations due to heightened sensory responses [44, 45]. In the current study, all groups in the Petrie test generally fell within the category of individuals with normal perception. Therefore, the pain often associated with hypermobility is likely not attributable to sensitivity to environmental stimuli, as indicated by the Petrie test.

Proprioception plays a critical role in somatognosia and stereognosia [18]. The findings regarding proprioceptive deficits in hypermobile populations are inconsistent in the existing literature. While many studies have concluded that individuals with joint hypermobility experience impairments in proprioceptive sensation [23, 24], some studies have reported that the proprioceptive sense of these individuals is not affected [46]. A systematic review with meta-analysis concluded that individuals with hypermobility have statistically significantly poorer joint position sense and movement detection thresholds in the lower limbs [23]. In contrast, differences in proprioception between hypermobile and non-hypermobile individuals are less clear in terms of the upper limbs [23]. In our study, both somatognosia and stereognosia testing involved the upper limbs, which may have influenced our results. Most studies identifying proprioceptive deficits in the hypermobile population have focused on the knee [23, 24]. Therefore, assessing sensory processing concerning the lower limbs would be beneficial for future research. Moreover, proprioception differs between joints, with the fingers being most precise, followed by the ankle, knee, and shoulder. Evaluating proprioception and sensory processing across joints is crucial to explore whether excessive joint mobility impacts proprioceptive accuracy and sensory function [47].

Given that hypermobility is typically a genetic condition, each body part may adapt differently during development. Some studies have shown that children with joint hypermobility experience delayed motor development in early childhood, though most catch up with their peers by age two [48]. These varying adaptations can lead to different consequences and impairments for individuals or specific joints, contributing to variability in study results. Furthermore, it is important to note that all tests in this study were conducted in a static position, whereas injuries often occur during dynamic movements; thus, dynamic testing may yield different results. Additionally, factors beyond somatognosia and stereognosia, such as vestibular processing, tactile discrimination, kinesthesia, and sensorimotor integration, may also influence sensory processing and contribute to complaints in the hypermobile population. Since this study did not assess these aspects, further research is needed to explore their potential role in functional impairments and symptom presentation in hypermobile individuals.

The main limitations of this study include a small sample size, uneven group sizes, and an imbalanced gender distribution. With only nine males in the sample, it was not possible to conduct sex-based analyses. The sample size was sufficient to detect correlations larger than 0.4, meaning smaller correlations may exist but were not detectable in this study. Additionally, post hoc power analysis indicated that the study was powered to detect larger effect sizes (Hedge´s g = 0.85 for two groups or f-value = 0.4 for three groups comparison), which may have limited the ability to identify smaller, more subtle differences between groups. Additionally, this study focused on examining differences in central sensory processing but did not directly assess peripheral proprioception or intrinsic sensation, which represents a limitation. Future studies are needed to investigate these factors in hypermobile population including individuals with syndromes associated with hypermobility.

Conclusion

No significant correlations were found, and no differences in somatognosia and stereognosia measures were observed between non-hypermobile participants and all hypermobile participants. Furthermore, there were no significant differences between non-hypermobile, asymptomatic hypermobile, and symptomatic hypermobile individuals.

Although these findings suggest that somatognosia and stereognosia are not linked to hypermobility or associated complaints, interventions targeting body awareness training may still benefit hypermobile individuals with motor coordination issues or musculoskeletal pain by enhancing motor control, injury prevention, and movement planning.

The lack of group differences in sensory processing raises questions about adaptive mechanisms that may compensate for reduced proprioception in hypermobile individuals. These adaptations could explain why some hypermobile individuals function well without symptoms, while others experience pain and instability. Understanding and addressing these compensatory strategies across different hypermobility groups could help refine rehabilitation protocols and develop preventative strategies for at-risk subgroups.

These findings also highlight the need to re-evaluate assumptions about the role of higher-order sensory processing deficits in hypermobility and direct future research toward exploring other sensory modalities, including vestibular processing, kinesthesia, and sensorimotor integration. Future studies should incorporate sensory processing tests involving the lower limbs or other specific joints, as well as longitudinal designs, to better understand the mechanisms contributing to functional impairments in hypermobility and improve clinical interventions.

Author contributions
I.H.: conceptualization and study design, data analysis and interpretation, drafting the manuscript, finalizing and editing the manuscript. A.R.: data collection, data interpretation, drafting the manuscript. K.J.: data collection, data interpretation, drafting the manuscript. K.H-L.: revising and editing the manuscript, supervision and mentorship. All authors reviewed the manuscript.

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Data availability
The dataset is available in Zenado data repository: DOI: 10.5281/zenodo.14580656.

Declarations

Competing interests
The authors declare no competing interests.

Human ethics and consent to participate
The study protocol was approved Ethics Committee of the Faculty of Physical Culture, Palacký University (reference number: 97/2021) and adhered to the Declaration of Helsinki. All participants signed a written informed consent document to participate and to published the measured data.

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