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The effects of joint hypermobility on strength, proprioception, and functional performance

Esedullah Akaras✉, Gülnihal Deniz, Musa Eymir & Mehmet Sönmez

Generalized Joint Hypermobility (GJH) is characterized by increased joint mobility and may lead to proprioceptive deficits and altered muscle function. To investigate the relationship between Beighton scores and grip strength, elbow and knee proprioception, and upper and lower extremity performance and to compare hypermobile and non-hypermobile individuals in these domains. Eighty-three participants were classified as hypermobile (n = 46, Beighton 4–9) or non-hypermobile (n = 37, Beighton 0–3). Grip strength, elbow and knee joint position sense, and functional stability (CKCUEST, CKCLEST) were assessed. Pearson correlation and independent t-tests were used. Hypermobile individuals demonstrated significantly poorer proprioception at the elbow and knee ($p < 0.05$) but no differences in grip strength or functional performance. In the hypermobile group, Beighton scores positively correlated with grip strength and proprioception at 30° and 60° joint angles ($r = 0.422–0.674$, $p < 0.05$). GJH is associated with proprioceptive deficits, though joint mobility may improve grip strength. Functional stability was not compromised, indicating compensatory strategies may play a role. These findings underscore the importance of neuromuscular training in hypermobile individuals.

Keywords Hypermobility, Beighton score, Proprioception, Muscle strength, Functional performance

Generalized Joint Hypermobility (GJH) is characterized by an increased range of motion in multiple joints beyond the normal limits, which can be either asymptomatic or associated with musculoskeletal complaints and functional impairments[1]. GJH is reported to affect approximately 10–30% of the general population, with prevalence rates varying widely based on age, gender, and ethnicity[2]. Despite its prevalence, the functional and clinical implications of GJH remain underexplored, particularly in the context of physical performance, proprioception, and muscle strength.

Although often perceived as a benign condition, GJH can predispose individuals to a variety of health issues, including joint instability, chronic pain, and an increased risk of injury, especially in activities requiring joint stability and proprioceptive control[3]. The impact of GJH on muscle strength and physical function is complex and multifaceted. The current literature has reported mixed findings, with some indicating reduced muscle strength and proprioceptive deficits, while others suggest compensatory adaptations that enhance performance in specific physical tasks[4].

Proprioception, the ability to sense the position and movement of one's body parts, is particularly compromised in individuals with GJH due to altered mechanoreceptor function in the joint capsules and ligaments. Impaired proprioception not only affects joint stability but also increases the risk of injuries, particularly in weight-bearing joints such as the knees and ankles[5]. Furthermore, altered motor control strategies in hypermobile individuals, such as avoiding dynamic activities or adopting protective behaviors, can lead to long-term functional limitations and reduced physical activity levels[6]. Despite these potential adverse outcomes, there is growing interest in understanding the dual nature of GJH, as it may provide advantages in specific sports and physical activities that require a greater range of motion, such as gymnastics and dance[7]. However, these benefits are often offset by the increased risk of injury and chronic musculoskeletal issues[8]. This duality underscores the importance of evaluating and managing GJH in both clinical and athletic settings[9]. A significant gap in the literature exists regarding the dual nature of GJH. While some studies report enhanced performance in specific contexts, such as flexibility-demanding sports (e.g., gymnastics and dance), others highlight its association with proprioceptive deficits and musculoskeletal complications[8]. Additionally, there is limited research comparing hypermobile individuals with non-hypermobile counterparts to identify key differences in physical function, proprioception, and strength measures.

Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Erzurum Technical University, Erzurum, Türkiye. ✉email: esedullah.akaras@erzurum.edu.tr

The primary aim of this study is to investigate the relationship between Beighton scores, a widely used measure of joint hypermobility, and key physical parameters such as grip strength, elbow and knee proprioception, as well as upper and lower extremity performance. Additionally, this study seeks to compare hypermobile individuals (Beighton scores 4–9) and non-hypermobile individuals (Beighton scores 0–3) in terms of these parameters. By addressing these objectives, this research aims to fill critical gaps in the literature and provide insights into the functional implications of GJH. Furthermore, the findings are expected to inform the development of targeted interventions to improve joint stability and prevent injuries in hypermobile populations.

Method

Study design and participants

This study was conducted using a cross-sectional and comparative design. A total of 83 volunteer participants were recruited between October 1, 2023, and October 30, 2024, at Erzurum Technical University's Faculty of Health Sciences. Participants were aged between 18 and 35 years and grouped based on their Beighton hypermobility scores into hypermobile (n:46, Beighton scores 4–9) and non-hypermobile (n:37, Beighton scores 0–3) groups. The distribution of gender, physical activity levels, and prior athletic engagement was recorded to account for potential variability. Ethical approval for the study was obtained from the Erzurum Technical University Ethics Committee (Approval Number: 2023/10 – 03) in compliance with the Declaration of Helsinki. Written and verbal informed consent was obtained from all participants before the study.

Inclusion criteria

- Age between 18 and 35 years,
- A Beighton hypermobility score of at least 4 out of 9,
- No neurological, psychological, or cooperation problems.

Exclusion criteria

- Presence of chronic musculoskeletal disorders,
- History or current status of active sports injuries,
- Central or peripheral nervous system disorders affecting proprioception.

Measurement procedures

Demographic data collection

Participants' age, gender, height, weight, body mass index (BMI), and activity levels were recorded. Additionally, their sports history, including competitive or recreational involvement, was documented to contextualize the findings and ensure diversity in the sample. Participants' physical activity levels were collected using a structured self-report form and expressed as weekly MET minutes. Additionally, participants indicated whether they had a history of regular sports participation (recreational or competitive).

Beighton hypermobile score

Participants were assessed using the Beighton scoring system, which evaluates the following criteria:

- Placing palms flat on the floor without bending the knees (1 point).
- Hyperextension of the elbows beyond 10 degrees (1 point per side).
- Hyperextension of the knees beyond 10 degrees (1 point per side).
- Touching the thumb to the forearm (1 point per side).
- Bending the little finger backward beyond 90 degrees (1 point per side). The total score was evaluated out of 9 points, and scores were validated through a secondary examiner to ensure reliability.

Participants were categorized as hypermobile if they had a Beighton score between 4 and 9 and non-hypermobile if their score ranged from 0 to 3. This classification aligns with commonly used thresholds in the literature for young adults. While some criteria suggest a ≥ 5/9 threshold for adults under 50, a Beighton score of ≥ 4 is also widely accepted, particularly in physically active populations and musculoskeletal screening contexts[10,11]. The total score (maximum 9) was confirmed through secondary examiner validation to ensure inter-rater reliability[12].

Standardization and examiner reliability measures

Before all assessments, participants completed a standardized warm-up consisting of 5 min of low-intensity cycling (50–60 rpm) followed by 3 min of dynamic stretching, including upper and lower limb mobilization exercises. All tests were conducted in a controlled environment by the same experienced physiotherapist, who was trained and devices were calibrated in advance to ensure consistency across procedures. Standardized instructions were provided verbally and visually, including the examiner's demonstration of each test. Participants were allowed one practice trial before data collection to ensure understanding. To minimize inter-rater variability, only one examiner conducted all grip strength and proprioception tests, and the same devices and protocols were used for all participants. Intra-session reliability was further ensured by taking three repeated measurements and using their mean or best value (as specified for each test)[13].

Grip Strength Measurement: Measured three times for each hand using a calibrated dynamometer (Model: Jamar Hydraulic Hand Dynamometer, USA). The average value was recorded. Consistency of hand positioning and grip technique was ensured. The grip strength measurement was performed for the dominant side of the extremities.

Proprioceptive measurements: Proprioception was evaluated using a Dualer IQ Digital Inclinometer (J-Tech Medical, Midvale, UT, USA), a device commonly used in clinical and research settings for joint angle measurements. Participants were passively positioned at 30° and 60° flexion angles by the examiner for both the elbow and knee joints (dominant side)[14]. While blindfolded, they were asked to reproduce the presented joint angle actively. Each angle was tested three times, and the absolute angular error (i.e., the difference between the target and reproduced angle) was calculated. In this study, higher absolute JPS values indicate a greater angular error, which reflects **worse** proprioceptive accuracy. The mean of three trials was recorded for each angle and joint. To ensure consistency, the same examiner conducted all tests using standardized verbal instructions and demonstrations prior to each trial. This method has shown high reliability and validity in previous proprioceptive studies using digital inclinometers[15].

Functional performance tests

CKCLEST (Closed kinetic chain lower extremity stability Test)

The CKCLEST was used to evaluate dynamic lower limb stability and strength endurance. Participants began in a modified forearm plank position with their feet shoulder-width apart and elbows placed directly under the shoulders. They were instructed to alternately move one foot laterally (crossing over the opposite foot and returning to the original position) as rapidly as possible for 15 s. Each complete in-out movement of a single foot counted as one repetition. As with CKCUEST, the test was performed three times with a 60-second rest between trials, and the highest score was recorded. Care was taken to maintain core stability and avoid hip rotation or compensation. This test has been previously validated as a reliable measure of functional lower extremity performance[16].

CKCUEST (Closed kinetic chain upper extremity stability Test)

The CKCUEST was used to assess upper extremity functional stability and neuromuscular control. Participants assumed a standard push-up position with their hands placed 91.4 cm apart on two pieces of athletic tape affixed to the floor. From this position, they were instructed to alternately reach across the body with one hand to touch the opposite hand, crossing the midline as many times as possible within a 15-second interval. Each touch (left to right or right to left) was counted as one repetition. The test was performed three times, each separated by a 60-second rest interval. The highest number of touches among the three trials was used for analysis. This protocol has been shown to have high inter-rater and intra-rater reliability in young adult populations. It has high repeatability and reliability among examiners and is widely used for evaluating athletes[17].

Both tests are reliable and valid measures for assessing functional stability. The examiner standardized and monitored test durations (15 s each).

Statistical analysis

Data were analyzed using SPSS version 26.0. Descriptive statistics were calculated for all variables, including mean and standard deviation. The normality of data distribution was evaluated using the Shapiro-Wilk test. As data was normally distributed, Pearson correlation coefficients were used to assess relationships between Beighton scores and physical performance measures. Additionally, independent t-tests were used for group comparisons. A p-value of < 0.05 was considered statistically significant.

For the post-hoc power analysis, the joint position sense 30 degrees measurement parameter was used and the total power obtained for a margin of error of 0.05 and an effect size of 0.77 was determined as 0.96.

Results

This study included 83 participants, with 46 hypermobile subjects and 37 non-hypermobile subjects according to their Beighton scores. No statistically significant differences were observed between groups regarding demographic characteristics ($p > 0.05$), except the Beighton score ($p < 0.001$). There were no significant differences between the hypermobile and non-hypermobile groups in terms of physical activity level ($p = 0.072$) or prior sports participation ($p = 0.823$). This suggests that lifestyle and training background were comparable across groups and are unlikely to confound the main outcomes. Demographics of the participants are shown in Table 1.

As shown in Table 2, the hypermobile group demonstrated significantly greater absolute angular errors in both elbow and knee joint position sense (JPS) tests at 30° and 60° ($p < 0.05$ for all comparisons). This indicates poorer proprioceptive performance in hypermobile individuals compared to the non-hypermobile group. Other clinical assessments, including grip strength and functional performance, were evaluated by kinetic chain stability tests and demonstrated no significant differences between groups ($p > 0.05$). The comparisons of clinical measures between groups are shown in Table 2.

The Beighton score showed a moderate positive significant association with grip strength, elbow position sense at 30°, knee position sense at 30° and 60°, but no associations with elbow position sense at 30°, CKCUEST, and CKCLEST. The relationship of the Beighton score with grip strength, proprioception, CKCUEST and CKCLEST are shown in Table 3.

Discussion

The findings of this study underscore the multifaceted nature of Generalized Joint Hypermobility (GJH) and its implications on grip strength, proprioception, and functional performance. The positive correlation observed between the Beighton score and various measures of physical strength, such as grip strength, suggests that individuals with higher joint hypermobility may exhibit enhanced performance in certain areas. However, the lack of significant correlations with BMI, body weight, or closed kinetic chain tests highlights the complexity of GJH's impact on physical function. These results align with existing literature, emphasizing the need for a

Variables	Groups	Mean (SD)	*p*
Age (years)	Hypermobile	21.39 (1.58)	0.670
	Non-hypermobile	21.54 (1.57)	
Gender (male/female), n	Hypermobile	26/20	0.664
	Non-hypermobile	19/18	
Height (cm)	Hypermobile	168.41 (7.94)	0.423
	Non-hypermobile	170.19 (11.33)	
Weight (kg)	Hypermobile	66.15 (12.13)	0.60
	Non-hypermobile	71.75 (14.58)	
BMI (kg/m^2)	Hypermobile	23.20 (2.99)	0.74
	Non-hypermobile	24.69 (4.23)	
Beighton score	Hypermobile	7.08 (1.68)	< 0.001
	Non-hypermobile	1.43 (1.17)	
Physical Activity Level (MET-min/week)	Hypermobile	2655.82 (556.31)	0.072
	Non-hypermobile	2948.52 (635.98)	
Sports Participation (Yes/No), n (%)	Hypermobile	31 (67.4%)/15 (32.6%)	0.823
	Non-hypermobile	26 (70.3%)/11 (29.7%)	

Table 1. Demographic characteristics of groups. cm: centimeter, kg: kilogram, SD: standard deviation, BMI = body mass index, MET = metabolic equivalent threshold.

Variables	Groups	Mean (SD)	*p*
Grip Strength	Hypermobile	41.04 (16.25)	0.361
	Non-hypermobile	44.87 (20.69)	
Elbow JPS-30	Hypermobile	3.49 (1.48)	0.001
	Non-hypermobile	2.43 (1.27)	
Elbow JPS-60	Hypermobile	4.05 (1.31)	< 0.001
	Non-hypermobile	2.48 (1.24)	
Knee JPS-30	Hypermobile	2.84 (1.57)	0.014
	Non-hypermobile	2.05 (1.21)	
Knee JPS-60	Hypermobile	3.31 (1.48)	0.001
	Non-hypermobile	2.24 (1.32)	
CKCUEST	Hypermobile	20.56 (3.56)	0.892
	Non-hypermobile	20.43 (5.32)	
CKCLEST	Hypermobile	17.43 (3.56)	0.317
	Non-hypermobile	18.32 (4.49)	

Table 2. The comparisons of clinical results between groups. SD: standard deviation, CKCUEST: Closed Kinetic Chain Upper Extremity Stability Test, CKCLEST: Closed Kinetic Chain Lower Extremity Stability Test, JPS-30: joint position sense at 30 degrees, JPS-60: joint position sense at 60 degrees, The measurements of grip strength and proprioception were performed for dominant side of extremities.

Variables	[a]Grip Strength (*r*)	[a]Elbow JPS-30 (*r*)	[a]Elbow JPS-60 (*r*)	[a]Knee JPS-30 (*r*)	[a]Knee JPS-60 (*r*)	CKCUEST (*r*)	CKCLEST (*r*)
Beighton Score (r)	0.674**	0.422**	0.145	0.448**	0.624**	0.151	0.190

Table 3. Correlation of Beighton score with grip strength, proprioception and functional performance tests in hypermobile group. CKCUEST: Closed Kinetic Chain Upper Extremity Stability Test, CKCLEST: Closed Kinetic Chain Lower Extremity Stability Test, JPS-30: joint position sense at 30 degrees, JPS-60: joint position sense at 60 degrees, r: Pearson's correlation coefficient for results[a]: The measurement was performed for dominant side of extremities*$0.01 < p \leq 0.05$, **$0.001 < p \leq 0.01$, ***$p \leq 0.001$

balanced understanding of GJH's potential benefits and risks. The study provides valuable insights for clinical and athletic settings, advocating for targeted interventions to optimize joint stability and minimize injury risks in hypermobile populations.

The relationship between Beighton scores and grip strength has been examined extensively in the literature, with many studies reporting neutral or even negative associations. While our study identified a statistically significant positive correlation between Beighton scores and grip strength, this finding should be interpreted cautiously. Prior research, including Scheper et al.[18] and Rombaut et al.[2], has documented reduced or unchanged grip strength in hypermobile individuals compared to controls. Differences in participant characteristics, measurement protocols, and the presence or absence of musculoskeletal symptoms may explain these discrepancies. In our relatively young, active sample, the observed positive association may reflect compensatory neuromuscular adaptations or sample-specific factors, such as higher engagement in activities that enhance hand strength. Therefore, although the correlation is statistically valid in our data, it should not be generalized as evidence that joint hypermobility inherently improves grip strength. This finding may be due to young and active individuals of our sample. For example, factors such as sports history or hand-use habits of our participants may have affected the comprehension force. Therefore, the results should not be generalized.

Proprioception is vital in joint stabilization, motor control, and coordinated movement. In individuals with Generalized Joint Hypermobility (GJH), proprioceptive impairment is a frequently reported concern, mainly due to altered mechanoreceptor input from lax joint capsules and ligaments. Our study reinforces this association by demonstrating significantly greater absolute angular errors in joint position sense (JPS) at both the elbow and knee joints among participants with higher Beighton scores (as shown in Table 2), indicating poorer proprioceptive performance in the hypermobile group. These findings align with previous literature. For instance, Hall et al.[19] reported that individuals with hypermobility syndrome exhibited higher proprioceptive detection thresholds, particularly at the knee, increasing the likelihood of adopting biomechanically unsound joint positions and consequently raising injury risk. Smith et al.[5] also found reduced joint proprioception in individuals with benign joint hypermobility syndrome in a meta-analysis. Moreover, proprioceptive impairments in GJH are not limited to static postures but also extend to dynamic movement control, suggesting a widespread neurosensory deficit[7]. The functional implications of such deficits are profound. Impaired proprioception compromises joint stability and increases susceptibility to musculoskeletal injuries and early degenerative changes. Consequently, our results highlight the importance of integrating proprioceptive and neuromuscular training strategies into both clinical rehabilitation and athletic training programs for hypermobile individuals. Such interventions have been shown to improve joint stability, reduce pain, and enhance sensorimotor control[5], offering a targeted means to mitigate the biomechanical disadvantages of hypermobility.

The Beighton score has been associated with lower and upper extremity performance, particularly impacting proprioceptive awareness and muscle strength. Individuals with GJH demonstrate reduced lower extremity performance, which is evident through decreased walking and jumping capacity. This condition manifests as diminished grip strength and reduced proprioceptive sensitivity in the upper extremities, especially in the wrists and fingers[18]. In the upper extremities, reduced proprioceptive awareness and grip strength in joints such as the wrists and fingers have been documented[9]. However, in specific populations like athletes and dancers, this hypermobility may translate into performance advantages[6]. In this context, our findings demonstrate that individuals with high joint mobility, as assessed by the Beighton score, develop diverse adaptation strategies that significantly influence both lower and upper extremity performance. These findings highlight the importance of targeted strength and proprioceptive training programs for hypermobile individuals, emphasizing their role in improving functional outcomes and reducing injury risk[20].

The dual nature of GJH is well-documented in the literature, with mixed findings on its impact on physical performance. Our findings align with Sahin et al.[7], who reported proprioceptive deficits in hypermobile individuals, particularly in knee joints, compared to non-hypermobile individuals. Similarly, the hypermobile group in our study exhibited significantly higher proprioceptive deficits than the non-hypermobile group, confirming the role of altered mechanoreceptor function in proprioceptive impairment, as noted by Hall et al.[19].

However, our study identified a significant positive correlation between Beighton scores and grip strength, contrasting with the findings of Massy-Westropp et al.[3], who reported no significant relationship. This discrepancy may stem from differences in measurement protocols, participant characteristics, or compensatory neuromuscular adaptations unique to hypermobile individuals. Additionally, despite proprioceptive deficits, there were no significant differences in closed kinetic chain performance tests (CKCUEST and CKCLEST) between groups, suggesting that hypermobile individuals may employ alternative motor control strategies to maintain functional stability. This supports the findings of Baeza-Velasco et al.[6], who highlighted the adaptive capabilities of hypermobile individuals in physical activities requiring flexibility and neuromuscular coordination.

This study has several limitations that should be considered when interpreting the findings. First, the sample size was relatively small, which may limit the generalizability of the results to larger and more diverse populations. Additionally, the study's cross-sectional design prevents the establishment of causal relationships between joint hypermobility and the observed functional impairments. The reliance on self-reported data for certain variables, such as activity levels, may have introduced reporting bias. Furthermore, the absence of a separate control group entirely free of hypermobility features may limit the generalizability of the results. Another limitation is that we did not account for several potential confounding variables known to influence grip strength, such as hand size and anthropometry, upper-limb muscle mass, habitual physical activity or training status, and occupational hand use. Grip strength is strongly associated with hand dimensions and forearm muscle mass, and individuals engaged in manual work or regular resistance training often display higher grip values regardless of joint characteristics. The absence of such measurements means that differences in these factors between the hypermobile and non-hypermobile groups could have contributed to, or masked, the observed correlation. Future research should include anthropometric assessments and detailed activity profiles to control

for these variables and allow a more precise determination of the relationship between joint hypermobility and grip strength. Despite these limitations, the study has notable strengths. It employed a comprehensive and standardized approach to assess muscle strength, proprioception, and functional performance, ensuring consistency and reliability in the measurements. The inclusion of multiple tests, such as the Closed Kinetic Chain Upper and Lower Extremity Stability Tests, provided a robust evaluation of both upper and lower extremity function. Moreover, the focus on Beighton scores as a predictor of physical performance adds valuable insight into the nuanced effects of joint hypermobility on musculoskeletal health. This study contributes to the growing body of literature on hypermobility and underscores the importance of targeted interventions to minimize the functional challenges associated with this condition. Future research should address the identified limitations by incorporating larger, longitudinal studies with control groups.

Conclusion

This study highlights the intricate relationship between generalized joint hypermobility (GJH), as measured by the Beighton score, and various aspects of physical performance, including muscle strength, proprioception, and functional outcomes. The findings suggest that while higher levels of joint mobility may enhance performance in specific contexts, such as grip and knee strength, they are also associated with proprioceptive deficits and potential stability challenges. These dual effects emphasize the need for individualized approaches in assessing and managing hypermobile individuals, particularly in clinical and athletic settings. By employing standardized and comprehensive testing protocols, this research contributes to a deeper understanding of GJH's impact on physical function. The observed positive correlations between Beighton scores and specific strength metrics underline the potential adaptive strategies hypermobile individuals may develop to maintain performance. Nevertheless, proprioceptive deficits highlight the potential neuromuscular challenges associated with generalized joint hypermobility. While the study's limitations, including a relatively small sample size and cross-sectional design, restrict the generalizability of the findings, its strengths lie in the robust methodological approach and the focus on both upper and lower extremity performance. Future research should expand on these findings through longitudinal studies and larger, more diverse populations to further elucidate the complex interplay between hypermobility and physical performance. This work underscores the necessity for tailored strategies to support individuals with GJH, fostering improved outcomes and quality of life.

Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author, EA, on reasonable request.

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Author contributions
EA, GD, and MS conceptualized the study. EA and ME developed the methodology. ME and MS conducted the formal analysis and investigation. EA and GD prepared the original draft. EA, MS, and ME reviewed and edited the manuscript. EA and GD provided resources. EA and ME supervised the project. All authors read and approved the final manuscript.

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Declarations

Competing interests
The authors declare no competing interests.

Ethics approval and consent to participate
This study was approved by the Erzurum Technical University Scientific Research and Publication Ethics Committee (Meeting No: 10, Decision No: 03, Date: 06.09.2023) and was conducted in accordance with the Declaration of Helsinki. All participants provided informed consent prior to participation.

Consent for publication
Not applicable.

Additional information
Correspondence and requests for materials should be addressed to E.A.

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