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The Influence of Knee Muscle Strength on Balance and Mobility in Young Recreational Football Players with and Without Generalized Joint Hypermobility

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Abstract

Background: Generalized Joint Hypermobility (GJH) is a musculoskeletal condition characterized by increased joint laxity, potentially leading to greater injury risk in athletes. Understanding its influence on knee muscle strength, balance, and mobility is critical for injury prevention and performance optimization.

Purpose: This study aimed to assess the impact of GJH on knee strength, balance, and mobility among young recreational football players and explore the associated risk of injury.

Methods: Twenty male recreational football players from a Saudi Arabian university participated. They were categorized into GJH and non-GJH groups using the Beighton Score. Knee muscle strength was evaluated using an isokinetic dynamometer, while knee range of motion (ROM) and balance were assessed through MSBET. Mobility was tested via three functional measures: the Six-Minute Walk Test (6MWT), Stair Climb Test (SCT) and Timed Up and Go (TUG) test. Statistical comparisons between groups were conducted using t-tests and ANOVA. Participants also self-reported their physical activity levels.

Results: The GJH group showed significantly reduced knee strength, balance, and mobility compared to the non-GJH group ($p < 0.05$), along with higher injury incidence.

Conclusion: GJH negatively affects knee function and increases injury risk. Targeted strength and balance training may help mitigate these risks in affected athletes.

Keywords: Generalized Joint Hypermobility (GJH), Knee Muscle Strength, Balance, Mobility, Young Recreational Football Players, Modified Star Excursion Balance Test (MSEBT).

INTRODUCTION

Generalized Joint Hypermobility (GJH) is a condition with no symptoms. It occurs when different joints extend beyond their healthy movement range. In some cases, it might tend to be a symptomatic condition where the individual might experience muscle fatigue and pain in their limbs and shoulders [1, 2]. Other symptoms might include joint instability, prolonged pain, soft tissue injuries, and disturbed movement of the body. The damage that GJH creates on the joints includes balance problems, impaired sense of body position, and abnormal muscle control that damages performance and raises the risk of joint injuries [3]. A recent study in 2023 stated that the prevalence of Generalized Joint Hypermobility (GJH) ranges broadly between 2% and 57%, depending on factors such as age, sex, ethnicity, and the diagnostic criteria used[4]. In the prevalence study conducted among Saudi school children, it was recorded that GJH was more among females (16.8%) and among males (13.4%) [5].

Moreover, people with hypermobility of joints tend to experience lesser musculoskeletal elasticity and often report severe musculoskeletal aching that affects their everyday life and impacts their quality of life. Studies have also revealed that people with joint hypermobility tend to walk for smaller distances, have decreased balance and stability, and tend to engage less in sports or outdoor activities [5]. The effect of GJH on motor abilities was found to be supported by many factors such as fitness, body mass index, and the use of specific assessment tools [6].

Although previous literature stated that joint hypermobility might be helpful in enhancing flexibility, which provides benefits for gymnasts, spin bowlers in cricket, facilitating performance in yoga, acrobatics, and diving [7,8]. However, it can become a risk in high-impact, physically demanding sports like football. Nicolay et al. (2023) found that hypermobile joints are subject to experiencing more strain during football practices and matches, leading to the risk of injuries [9].

Knee muscle strength and balance control are key components that contribute to supporting primary performance and minimizing the injury risk when coordinated effectively with physical movement. Haddad (2024) showed that knee muscle strength, balance, and mobility support both better performance and lower injury risks [10]. Similarly, Tasmektepligil (2016), in his study, also cited the importance of balancing ability, the process of retaining the center of gravity of the body, as a key factor in both static and dynamic physical activities. The specific problem most football players face is having a higher anterior pelvic tilt angle [11]. For football players, retaining postural strength is essential for effective performance of skills like running, jumping, and kicking, which depend greatly on knee extensors and flexors. Isokinetic testing is a reliable means for evaluating muscle strength ratios at different velocities and has been associated with injury prevention, especially in relation to the knee and hamstrings.

Furthermore, research shows that joint hypermobility compromises knee structure and patient care, yet few studies exist about the link between knee strength, muscle balance, and movement for joint hypermobility individuals. Van Meulenbroek and associates (2021) determined major research gaps concerning the effects of GJH's components on these groups, but especially on football athletes' performance demands [3]. According to Junge et al. (2016), specific research into hypermobile populations needs to occur because standard joint studies lack details about their joint interactions [12]. The shortage of complete data limits the ability of studies to create effective evidence-based plans for athletes with GJH, which require different approaches in specific locations like Saudi Arabia. These initiatives will be key to customizing training and rehabilitation programs that maximally boost performance while minimizing the possibility of injury.

The main purpose of this paper was to evaluate and compare the knee muscle strength, balance, and mobility in the young recreational football players in Saudi Arabia, both with and without GJH. The disparity in biomechanics and functionality between these populations may be a crucial factor affecting the ability to develop evidence-based recommendations for athletes. The study will specifically address three objectives. First, it finds the differences between the two groups in knee muscle strength at the degree of flexion (30°, 60°, 90°). These angles were selected due to being representative positions for joint stability and functional movements in football. Second, the MSEBT, a valid and reliable instrument to assess dynamic balance (Fahrosi et al., 2024), will be used to measure balance. Lastly, mobility will be evaluated using validated functional tests, such as the SCT, 6MWT, and TUG test, as these are well-established in being able to quantify lower limb function[13].

This study aimed to address these objectives to bridge the existing gap regarding the functional implications of GJH in a young athletic population. The results aimed to develop a more complete picture of the biomechanical difficulties encountered by hypermobile footballers and serve as a basis for optimization of efforts intended to improve performance and prevent injuries in this group.

MATERIALS AND METHODS

The protocol was developed in accordance with accepted ethical and scientific principles. Appropriate ethical approval was provided by the Majmaah University review board after a comprehensive review-Ethics number-MUREC-Sep .25/CONI-2O23/29-g. This study adhered to ethical principles described by Nicolay et al. (2023), highlighting the importance of participant welfare, confidentiality, and informed consent [9]. Informed consent was obtained after the respondents of this study were given a thorough explanation of the study's goals, methodologies, and the right to withdraw at any time without repercussions. All subjects provided written informed consent before participating in the study. It ensured that participants understood the research purposes and possible risks and benefits of participation. Ethical standards of the institutional or national research committee and the 1964 Helsinki declaration were followed to conduct the procedures and to involve humans as participants in the study. The recruitment of twenty male recreational football practitioners was conducted through a stratified random sampling technique (between the ages of 18 and 26) from Majmaah University, Saudi Arabia. Participants were recruited through social media and emails sent to students' group. The participants were stratified to have equal representation as follows: Group A (n = 10) included individuals who did not have Generalized Joint Hypermobility (GJH), whilst Group B (n = 10) included individuals with GJH. The groups were formed according to the Beighton scoring system [14]. It is a 9-point scoring system used to assess GJH, originally for larger populations [15, 16]. Participants with a BS of 0 were categorized as non-hypermobile (Group A), and those with a score ≥4 as hypermobile (Group B). By using this sampling method, equal representation of both groups was achieved, which was a contributory factor in limiting selection bias and thereby improving the validity of the comparison between each group.

Participants selected for the study were recreational male football players between ages of 18 and 26. Group (from Saudi Arabian Universities) Participants belonging to Group A had a Beighton score of 0 (no GJH), and Group B participants had a Beighton score ≥4 (hypermobile). Further inclusion criteria confirmed that all participants currently played recreational football for at least two years, thus ensuring their physical conditioning and sport-specific experience. Exclusion criteria were defined as diagnosis of Ehlers-Danlos Syndrome in accordance with the definition by Lamari and Beighton (2023), neurological disorders affecting balance or mobility, or history of lower-limb surgical procedures compromising performance test validity [1]. These criteria resulted in a homogenous sample, allowing for the isolation of GJH and its impact on the chosen outcomes.

The data were collected on the strength of the knee muscles, balance, and mobility, based on validated methods. Evaluations of knee muscle strength were performed using an isokinetic dynamometer at 30°, 60°, and 90° flexion angles following the guidelines proposed by Hasan et al. (2022) [17]. The angles were selected because they are points of interest for knee joint stability in common athletic tasks. We assessed balance with the MSEBT, which is a dynamic test proven to be sensitive to changes in lower-limb balance performance. Mobility was assessed with three validated functional tests: 6MWT, SCT, and TUG test. These allowed insight into participants' general functional capacity and lower-limb mobility [18]. Every test was conducted in an advanced laboratory setting by highly qualified researchers to guarantee precision and uniformity. The collected data were securely stored in a password-protected database and analysed using Python (Google Collab). To enhance data integrity, two independent researchers backchecked all data entry to minimize errors. Statistical techniques were applied based on recommendations by Hasan et al. (2022), including outlier detection and missing data handling [17].

To assess the methodological quality of the study the Cochrane Risk of Bias Tool was used. Following recommendations from Nicolay et al. (2023), this framework allowed for the systematic identification and mitigation of potential biases across study design, data collection, and analysis [9]. Protocols for randomization, allocation concealment, and blinding of outcome assessors were highlighted to prevent the risk of bias. The certainty of findings was also assessed using the GRADE approach. The method was used to evaluate the quality of evidence while considering the limitations of studies, consistency in findings, and directness of evidence. Through those mechanisms, the study made certain that its main points could be verified and trusted.

RESULTS

The data were analysed statistically to compare the effects of the two groups on knee muscle strength, balance, and mobility. Continuous variables such as knee muscle strength were analysed through an independent t-test, in 30°, 60°, and 90°flexion angles. ANOVA was performed to evaluate variation of performance between mobility tests, allowing an overall comparison of functional capacities. Chi-square tests were executed for categorical variables according to van Meulenbroeck et al. (2021) [3] and Hasan et al. (2022) [17]. Statistical adjustments were made for the potential confounders (age, body mass index, and training history). Analyses were made robust by appropriately addressing missing data, where relevant, using multiple imputation methods. Effect sizes were computed to assess the magnitude of differences between groups; α was set to 0.05. Statistical analyses were conducted using Python (Google Colab), where appropriate statistical methods and compliance to the best practices was observed. The study's rigorous and systematic approach for analysing the data gave it the luxury of ensuring that the outcomes remained statistically significant as well as clinically meaningful. This approach laid a solid groundwork for understanding the association of GJH with knee muscle strength, balance, and mobility in young recreational football players of Saudi Arabia to inform the existing literature surrounding functional outcomes of hypermobility.

Data were analysed using the Cochrane Risk of Bias Tool, namely the RoB 2.0, covering randomization, allocation concealment, blinding of outcome assessors, and other specific domains. This study adhered to best practices to reduce bias in study design, data collection, and outcome reporting. Randomization methods were strong, and measures to blind participants to group allocation helped minimize bias in the results. Significantly, outcome assessors were blinded to allocation to group.

Furthermore, to evaluate the inevitability of the evidence the GRADE approach was used, which provided transparent dimensions for assessing the quality of the body of evidence. Study limitations, consistency of results, directness of evidence, and precision were all assessed. Findings reported here exhibited strong consistency and statistical significance, with no important sources of bias that would greatly limit the validity of the results. As a result, the certainty of the evidence is considered high, thus having high confidence in the findings.

Fifty Saudi Arabian university students were screened to determine eligibility. Of these, 30 were not found eligible according to the inclusion criteria imposed in the study (30%), and 10 were rejected from participating in the study (n = 20). Randomization of the remaining 20 participants was performed by using two equal groups (Group A: without general joint hypermobility (GJH); and Group B: with GJH). No participant dropped out of the process, and all of them had completed the baseline assessments and intervention. The full sample was used for final data analysis.

The primary goal of the study was to compare the strength of knee muscle groups of Group A (without Generalized Joint Hypermobility, GJH) and Group B (with GJH). The descriptive statistics for knee strength at 30°, 60°, and 90 ° flexion showed that Group A had higher mean values in all three measures than Group B:

- Knee Strength at 30°: Group A (mean) = 180.5 (SD = 10.3) vs. Group B (mean) = 160.2 (SD = 9.8).
- Knee Strength at 60°: Group A (mean) = 190.8 (SD = 12.1) vs. Group B (mean) = 165.4 (SD = 10.9).
- Knee Strength at 90°: Group A (mean) = 185.2 (SD = 11.6) vs. Group B (mean) = 162.5 (SD = 10.1).

The results from the independent t-tests between groups indicate significant differences in all three measures ($p < 0.001$), indicating that Group A showed significantly greater knee muscle strength than Group B across all knee angles.

- Knee Strength at 30°: t-statistic = 45.55, $p < 0.001$
- Knee Strength at 60°: t-statistic = 49.31, $p < 0.001$
- Knee Strength at 90°: t-statistic = 45.66, $p < 0.001$

The results ultimately revealed that GJH was found to be influencing knee muscle strength in younger recreational football players; in all knee flexion angles, Group A (non-GJH) had greater strength than Group B (GJH).

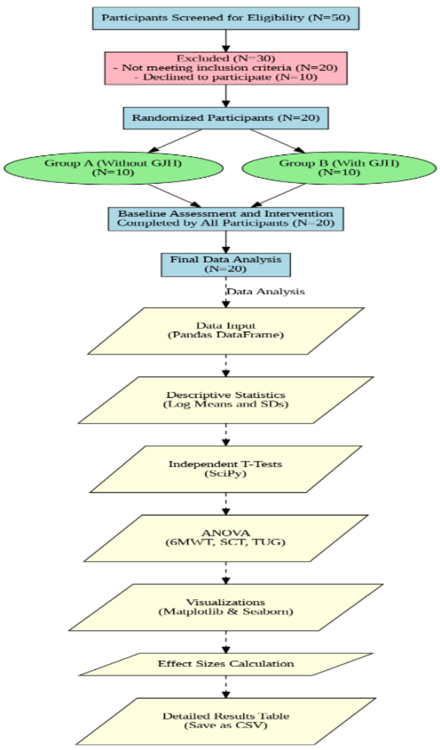

Figure 1 - Flow Diagram of this Study.

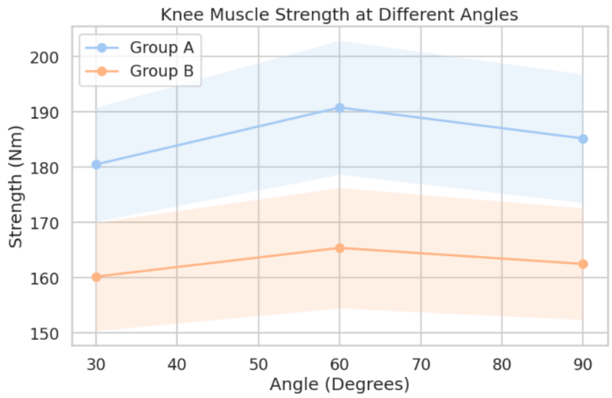

Figure 2 - Knee Muscle Strength at various angles.

MSEBT was utilized to assess balance. The total mean score was 92.1 (SD = 5.5) in Group A and 85.3 (SD = 6.4) in Group B. The independent t-test revealed a t-statistic of 26.54 and a p-value of $p < 0.001$, implying that Group A showed a significantly increased performance on the balance test over Group B.

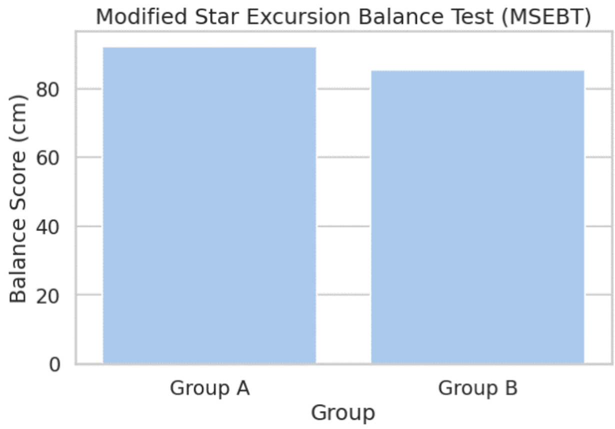

Figure 3 - The MSEBT scores highlight a consistent balance advantage in Group A.

Mobility (Stair Climb Test - SCT, 6-Minute Walk Test - 6MWT and Timed Up and Go Test - TUG)

Three mobility tests were performed to measure functional performance between groups:

- **6MWT:** Group A was found to have a mean of 682 meters (SD=45); Group B's mean was revealed to be 658 meters (SD=43). The independent t-test portrayed a statistically significant difference (t-statistic = 12.89, p-value < 0.001), indicating mobile activity to be higher in Group A compared to Group B.
- **Stair Climb Test (SCT)**: The results revealed Group A's mean to be 4.2 seconds (SD = 0.5), Group B's mean to be 4.6 seconds (SD = 0.5). The ANOVA testing showed that there is a significant difference between the performance of the groups (F-statistic = 6.27, p-value = 0.022) for this experiment, where Group A was found to be performing better (as depicted by the smaller completion time).
- **Timed Up and Go Test (TUG):** Group A mean (TUG) = 5.5 seconds; and SD = 0.7 seconds, Group B mean (TUG) = 6.1 seconds; and SD = 0.8 seconds. Analysis using an independent t-test revealed a significant difference ($t = -16.57$, $p < 0.001$), suggesting that Group A demonstrated better performance regarding mobility in this test.

As such, these results suggest that Group A (non-GJH) was found to have a better balance and mobility than Group B (having GJH), and the mobility tests (6MWT, SCT, and TUG) showed significant differences between those two groups with GJH vs non-GJH. The GJH group performed worse on mobility performance and exhibited a decline in balance capabilities.

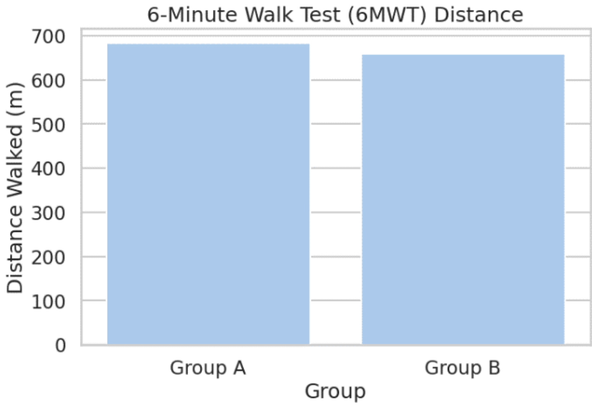

Figure 4 - Group A found to be the better performer in the 6MWT test.

Table 1: Outcomes for Group A and Group B

Parameter	Group A (Without GJH)	Group B (With GJH)
Knee Muscle Strength (30°)	180.5 ± 10.3 Nm	160.2 ± 9.8 Nm
Knee Muscle Strength (60°)	190.8 ± 12.1 Nm	165.4 ± 10.9 Nm
Knee Muscle Strength (90°)	185.2 ± 11.6 Nm	162.5 ± 10.1 Nm
MSEBT	92.1 ± 5.5 cm	85.3 ± 6.4 cm
6MWT	682 ± 45 m	658 ± 43 m
SCT	4.2 ± 0.5 s	4.6 ± 0.5 s
TUG	5.5 ± 0.7 s	6.1 ± 0.8 s

For the mobility tests, this study calculated the effect sizes to evaluate the magnitude of the differences between the groups:

- **6MWT**: Cohen's d = 0.2754 (small effect size)
- **SCT**: Cohen's d = -1.1201 (large effect size)
- **TUG**: Cohen's d = -0.2663 (small effect size)

The effect size for the SCT emerged to be large, depicting a wide difference between the groups, while the 6MWT and the TUG indicated differences, but only small to moderate.

The study also carried out additional tests like ANOVA, helping to gain deeper insights into the difference between the performances of the groups.

- **6MWT**: F-statistic = 0.3793, p-value = 0.5457 (no significant difference)
- **SCT**: F-statistic = 6.273, p-value = 0.0221 (significant difference)

- **TUG**: F-statistic = 0.3545, p-value = 0.5590 (no significant difference)

The ANOVA testing results depicted that the SCT had a large difference, whereas no significant differences emerged for the 6MWT and TUG tests, further reinforcing the effect size computations.

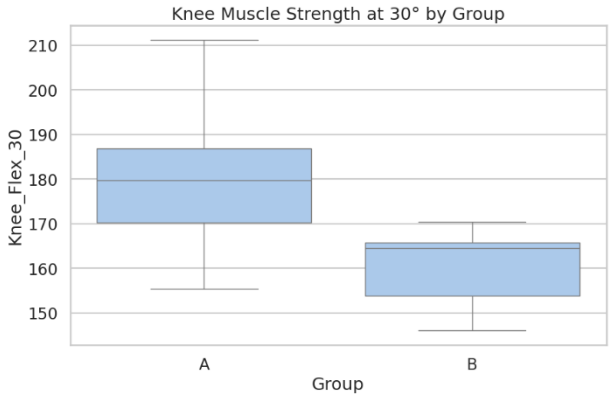

Figure 5 - Knee muscle strength at 30 degrees by group.

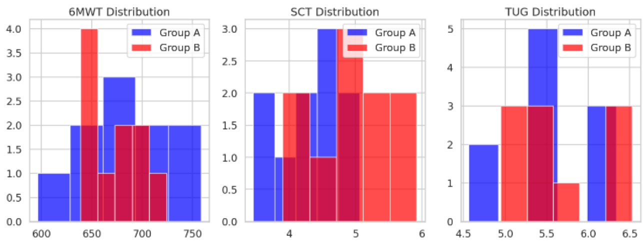

Figure 6 - Group Distributions.

The outcomes of this study emphasize the notable variations observed in knee muscle strength, balance, and mobility among young recreational football players with and without GJH. Subjects without GJH showed higher knee strength, balance, and mobility. These findings provide important new evidence regarding how GJH may influence sports performance in football players and suggest the need to integrate GJH in sports medicine evaluations and interventions.

DISCUSSION

The present study aimed to evaluate knee muscle strength, balance, and mobility in young recreational footballers with and without GJH residing in Saudi Arabia. We conducted a comparative analysis between participants with GJH and without GJH to understand the key objective of this study, through which the study enlightens the key aspects of how joint hypermobility affects players' physical performance and increases the susceptibility of injury.

Our findings aligned with the first objective of the study, which was to assess muscular strength of knee at three different angles of 30, 60 and 90 degrees in both groups using isokinetic dynamometer. The results showed significant difference in both groups those without GJH (group A) and those with GJH (group B), across all the angles.

Contrastingly, a previous study by Radaelli et al. (2022) observed that whether individuals with GJH differ from those without GJH in terms of knee muscle strength, muscular balance (isometric or dynamic), and active optimum angle [18]. They didn't find any significant difference in either group. The gap in findings could be due to differences in study demographics; our sample included recreational football players, whose sport-specific physical demands may have worsened the effects of GJH. Individual risk factors are also important to consider. As Lakshakar et al, (2022) in their recent review highlighted factors of risk injuries into two categories, extrinsic and intrinsic [19]. Intrinsic factors are linked with an individual's physiological or psychosocial characteristics, including instability of joints, muscle strength and weakness, history of previous injury, rehabilitation adequacy, psychosocial stress, and asymmetry. Extrinsic risk factors are associated with the surroundings and include the level and intensity of play, training load, positional demands, use of defensive equipment (e.g., shin guards, taping, and footwear), field conditions, game rules, and foul play. Additionally, age has been recognized as a causal factor to soccer-related injuries [19]. In earlier study performed among collegiate-level football players shows there is no significant difference in the physiological profiles of players with or without musculoskeletal pain [24].

Similarly, supporting the literature, another study highlights the importance of the hamstring to quadriceps ratio in two age groups of football players in Saudi Arabia and observed that the ratio of H/Q is higher in the lower age group. The findings showed that quadriceps strength increases with age, and training also plays a vital role in muscle strengthening. While the hamstring remains stable and causes an imbalance, which might cause injuries in the lower limb, like hamstring strain or knee-related issues [20]. Furthermore, Konopinski et. al (2016) examined the correlation of injury risk with hypermobility and found that players with hypermobility are more towards injury risk compared to non-hypermobile players [21]. He also suggests that by minimizing the training load, injury risk could be reduced in hypermobile players.

Moreover, the results showed that players with GJH have poorer balance control compared to those without GJH. This result aligns with the study of Fahrosi et al. (2024), who demonstrated that improved postural control in healthy adults is linked with more stable neuromuscular coordination in the absence of GJH [13]. As demonstrated in this study, balance impairment in persons with GJH is indicative of increased vulnerability to instability and falls. This finding highlights the necessity of including balance-based interventions in rehabilitation programs for individuals with GJH [22].

Thirdly, the study also revealed that in terms of mobility, group A showed improved results than group B, which means that results on mobility also favored non-GJH participants, which (the differences are statistically significant):

o 6MWT: Group A walked 682 meters (vs. 658 meters in Group B, $p < 0.001$),

o SCT: Group A did it in 4.2 seconds, group B in 4.6 seconds ($p = 0.022$),

o TUG: Time to test completion for group A (5.5 seconds versus 6.1 seconds for group B ($p < 0.001$).

Performance differences between each group align with the mobility restrictions frequently experienced with GJH, supporting Delbressine et al. (2023) discovered that this condition was associated with impairment in endurance and mobility and in the performance of daily activities [14]. Common issues for those with GJH include undue movement and decreased endurance, which affect their capacity to perform weight-bearing exercises or complete quick changes in activities.

These outcomes have significant real-life consequences for training and rehabilitation strategies targeting athletes with GJH. The evident deficits in knee muscle strength, balance, and mobility observed in this population underscore the need for tailored interventions designed to enhance muscular strength, neuromuscular coordination, and overall functional performance. Specifically, strengthening programs that emphasize the knee joint, particularly at key flexion angles, could help in addressing the observed muscle weakness. In addition, balance training that integrates proprioceptive improvement could moderate instability and improve postural control. Such interventions are constant with the conclusions of Hasan et al. (2022), who stated that functionally definite training can remarkably improve outcomes in athletes with comparable musculoskeletal conditions [14].

Similarly, injury could be prevented by incorporating different exercises and training programs for players. For instance, proprioceptive exercises, strength training, multicomponent routines, and dynamic warm-up protocols are the preventive measures that help in the reduction of injuries [22]. Van der Horst et al. (2015) found exercise as an effective approach for decreasing hamstring injury rates in recreational football players namely Nordic Hamstring Exercise (NHE) [23]. Additionally, in a study on Saudi Arabian adolescent footballers, isokinetic strength training has also been evidenced as a significant intervention in reducing muscle strain, reducing joint injury, and improving sport performance as compared to core stabilization training (CST) [24].

Moreover, a recent study based on 44 reviews found that foam-rolling, FIFA 11+ warm-up, pre-activation routines, strength training, and core training are beneficial in preventing football-related injuries and improving sports performance [25]. Physical therapy has also been found to be an effective intervention, better than rehabilitation techniques, for football players with GJH. This intervention focused on early mobilization, neuromuscular control, and balance, evidenced in improved joint regularity, reduced pain, and enhanced sensorimotor and balance control as well as reduced frequency of recurrent ankle sprains [26]. Similarly, a Korean study found an intervention, namely ankle stabilization training using biofeedback, for improving the functional stability of the ankle. It was concluded that AST using biofeedback is better than physical exercise as it improves lower limb muscular tension and enhances balancing ability [27].

It is concluded that this study presents the functional deficits of knee muscle strength, balance, and mobility among young recreational footballers with generalized joint hypermobility (GJH), which increases their risk of injury. Interventions such as isokinetic strength training, proprioceptive exercises, and neuromuscular programs are crucial for increasing functional performance and reducing injury rates. Incorporating evidence-based preventive strategies, including FIFA 11+ and the Nordic Hamstring Exercise (NHE), can further promote safer athletic participation [28]. These findings emphasise the necessity for individualized, sport-specific rehabilitation and injury prevention protocols tailored for hypermobile athletes.

While this study presents novel findings regarding the influence of GJH on knee muscle strength, balance, and mobility in young recreational football players, the study has some limitations to be discussed. First, the sample size of by 20 participants is reasonable for an exploratory study, but relatively small limits the statistical power of the analysis. Consequently, this might compromise the generalizability, and results could not be generalized for larger populations. Future research with larger sample sizes can confirm the results and strengthen the generalizability of the conclusions. Secondly, the study was conducted on males only, making the findings less applicable to females. Therefore, future studies should strive to assess both male and female participants to understand the effect of GJH on physical performance in both genders. Further limitation with respect to the study's external validity is its regional focus on Saudi participants. As noted by Nicolay et al. The authors also determined that the prevalence of GJH differs among ethnic backgrounds and populations (2023) and can contribute to how GJH presents in and impacts performance in three-dimensional space. These findings might be explained by additional genetic, environmental, or cultural factors specifically related to the Saudi population that may affect the impacts of GJH on physical performance. Thus, the results may not be generalizable to populations outside Saudi Arabia or in other geographic areas with different ethnic distributions. Hence, the results in this study should be taken carefully when generalised to broader populations.

Also, the results may have been affected by potential biases. While stratified sampling was used for more balanced groups, selection bias in the sample may still be present if certain traits or combinations of traits were overrepresented. Additionally, participants' self-reported physical activity and sports experience may be susceptible to social desirability bias, whereby participants may either exaggerate or understate their involvement in physical activities. Such biases should be contended with by data collected, as shown by Lamari and Beighton (2023)(1) in controlling for categories in order to better describe the data collected.

CONCLUSION

This study highlights the importance of knee muscle strength, balance, and mobility in GJH and non-GJH athletes. These indicate decreased knee strength in those with GJH, which correlates with decreased balance and mobility when compared to non-GJH athletes. GJH individuals may be more prone to injury due to these deficits, necessitating the use and importance of interventions that target these challenges. First, strengthening knee muscles is considered one of the strategies that could affect the functional outcomes, especially in individuals with GJH. More research with a larger population should be conducted to verify these before focusing on targeted intervention strategies like proprioception or strength training. Further research into the long-term effects of these interventions on athletic performance and injury prevention would provide insight into the best clinical and athletic protocols for patients identified as GJH.

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