

RESEARCH ARTICLE

Muscle strength, muscle power and body composition in college-aged young women and men with Generalized Joint Hypermobility

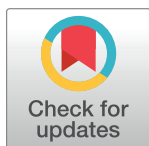
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Abstract

The aim of this study was an evaluation of the musculoskeletal system in women and men with Generalized Joint Hypermobility (GJH). The study included 87 participants— 40 with Generalized Joint Hypermobility (aged 21.2 ± 1.8 years) and 47 (aged 21.0 ± 1.3 years) in the control group (CG). The study included the Beighton score, the measurements of body composition, muscle flexibility (Straight Leg Raise test, Popliteal Angle test, Modified Thomas Test), and the measurements of muscle strength and muscle power. T-test and Mann-Whitney U Test were applied to assess the differences between independent groups. The study showed that there were no significant differences ($p > .05$) in the assessed body composition and the muscle flexibility between both women and men with GJH and the participants in the CG. Under isokinetic conditions for the non-dominant lower extremity, men from the CG received significantly higher ($p = .02$) flexion peak torque at $180^\circ/s$ angular velocity. Women from the CG received a statistically significantly lower ($p = .04$) F/E ratio at $180^\circ/s$ velocity. Under isometric conditions for both women and men with GJH, there were no statistically significant differences ($p > .05$) in the maximum torques in knee extension and flexion compared to the CG. For women and men with GJH, the maximum power in the lower extremities and jumping ability were not significantly different ($p > .05$) compared to the CG participants. The body composition, muscle flexibility, muscle strength, and muscle power of adults with Generalized Joint Hypermobility did not differ compared to healthy participants. The fact that there are no differences does not exclude the efficacy of strength training in increasing levels of muscle strength and its impact on body posture and proprioception or coordination.

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Introduction

Generalized Joint Hypermobility (GJH) is defined as an increased range of motion in large and small joints, taking into account age, gender, and ethnicity [1–4]. The prevalence of GJH is reported to be from 10% to 20% [5]. It occurs three times more often in women than in men [6,7]. GJH is characterized by increased mobility of the peripheral and interstitial joints, tenderness of the articular capsules, and consequently, a decreased mechanical and stabilizing quality of the joints [4]. GJH is a musculoskeletal disorder without any other systemic diseases in contrast to the Benign Joint Hypermobility Syndrome (BJHS). In the BJHS case, chronic pain is characteristic [4,8]. The pathophysiology of the GJH lays in the disproportion between the increased quantity of type I collagen relative to type III [9]. Researchers confirm the coexistence of increased mobility in joints with spinal and peripheral joint pain and postural disorders such as idiopathic scoliosis, flat feet, impaired proprioception, and coordination [10–14]. In children with hypermobility, a lower level of physical activity, and consequently reduced muscle strength and physical performance can be observed [14].

GJH diagnosis is based on clinical symptom analysis [4]. The most commonly used diagnostic method is the Beighton 9-point test [1,15]. Other methods assessing GJH are the Carter and Wilkinson test, the Marshall test, and the Bulbena scale [12].

There is no causal treatment of joint hypermobility [16]. The therapy should be based on the individual needs of patients, and clinical expertise [16,17]. A physiotherapist's knowledge of GJH tends to be relatively low. Inadequate physiotherapy including flexibility exercises or aggressive manual techniques in hypermobile joints can cause a patient's health condition to deteriorate. Therefore, it seems necessary to include specifications for the GJH assessment of participants with GJH in standard physiotherapeutic diagnostics [10,18]. According to Keer and Grahame [18], physiotherapy is the pillar of treatment in the musculoskeletal consequences for GJH. Specific training can improve the condition of the muscular system as a dynamic stabilizer [19]. Existing published analysis suggests that there are no evidence-based strategies in the treatment of GJH. Case studies confirm the effectiveness of physiotherapeutic interventions in the treatment of GJH but leave many ambiguities [17].

The aim of this study was an assessment of the musculoskeletal system of women and men with GJH. It included the measurements of body composition, pelvis-hip complex muscle flexibility, muscle strength, muscle power, and jumping ability.

Materials and methods

Participants

The recruitment process began with the announcement of a research project at the university. The next step was the informing meeting about the aim and protocol of the study. Then one researcher conducted the measurements of hypermobility, muscle flexibility, strength, and power. The study was conducted on 91 participants willing to participate in the research project. During the first meeting, all participants were informed about the aim and protocol of the study and the option to discontinue their participation at any time.

The exclusion criteria were: Benign Joint Hypermobility Syndrome (the Brighton criteria), knee varus or valgus (measured Q angle), orthopedic, rheumatological, neurological or genetic disorders, pain in lower extremities and lower back pain (interview information). Three participants were excluded because of chronic pain and one due to knee arthroscopy.

Ultimately, the research included 87 participants— 40 with GJH (25 women and 15 men) and 47 (28 women and 19 men) classified as the CG.

Before the study, the number of participants was calculated. 17 participants were recommended for each group. The analysis was conducted with 95% of confidence interval ($\alpha = 0.05$), power of test 0.80, and sigma 0.15 N m/kg of body weight. The sigma was specified after the preliminary study.

In this study, all musculoskeletal performance tests were characterized by reliability and repeatability [4,20–25]. The participants did not know to which group—with GJH or control the participants belonged.

The local ethics committee (Senacka Komisja Etyki Badań Naukowych—SKE01-2/2014) consent was obtained prior to the study. Written participants' consent was obtained.

Assessment of generalized joint hypermobility

The assessment of GJH was carried out using the 9-point Beighton score [20]. It included: a) abduction of the thumb to the forearm, b) knee hyperextension above 10 degrees, c) extension of the metacarpophalangeal joint in the 5th finger above 90 degrees, d) elbow hyperextension above 10 degrees and e) placing flat hands on the floor. Each positive test would score 1 point. Females with ≥ 5 and males with ≥ 4 scores in the Beighton score were included in the GJH groups [26,27]. The single-blind test was applied. The assessment was carried out at the goniometer (MSD Europe Bvba, North America).

Assessment of body composition

The measurement of body composition was carried out at Tanita-BC 418 MA (Tanita Corporation, Japan). The assessment included the quantity of fat mass (%), fat-free mass (kg), and total body water (kg). Weight of clothing [28] was assumed as 0.5 kg.

Assessment of pelvic-hip complex muscle flexibility

The measurement of hamstring flexibility was carried out during the Straight Leg Raise Test (SLR) and the Popliteal Angle Test (PA) [20,29]. One-Joint Hip Flexors (O-JHF) and Two-Joint Hip Flexors (T-JHF) flexibility were conducted during the modified Thomas Test. The assessment was performed by two researchers. The first researcher (R1) measured the angle of the joint of the lower extremity with AMI digital inclinometer (OPIW, Poland), which was reset into a horizontal position before each measurement. The second researcher (R2) carried out the test and stabilized the participant's position. The mean value of the three measurements was taken into statistical analysis [20]. The measurements were carried out for both lower extremities.

Straight Leg Raise Test

The participant lay in a supine position with the target lower extremity relaxed. The second lower extremity was positioned behind the table for the lumbar spine and pelvis stabilization. The R2 controlled the position of the participant and raised their lower extremity with the knee extended to the first resistance of the hamstring. The R1 assessed the range of hip flexion with an inclinometer, which was placed 10 cm proximally to the patella [20].

Popliteal Angle Test

The participant lay in a supine position with the hip flexed to 90°. He stabilized his thigh position with both hands. The R2 controlled this position with a goniometer, which was set over his greater trochanter. Its stationary arm was located along the trunk (parallel to the table) and the mobile arm along the femur. In this position, the participant had to straighten his knee.

The R1 assessed the popliteal angle with an inclinometer, which was placed 10 cm below the tibial tuberosity. The untested lower extremity was extended and relaxed [20].

Modified Thomas Test

A Modified Thomas Test was used to assess the flexibility of O-JHF and T-JHF [20]. The participant lay in a supine position with their pelvis close to the edge of the table. The untested lower extremity was flexed at the hip and knee joint to stabilize the pelvis and the lumbar spine. The participant held this position with their hands. The R2 controlled and stabilized the participant's position. The tested lower extremity was placed in a relaxed position behind the table. The R1 assessed the range of hip extension or flexion with an inclinometer, which was placed 10 cm proximally to the patella.

During the T-JHF test, the participant and R2 were in the same position. The R1 assessed the range of knee flexion with an inclinometer, which was placed 10 cm below the tibial tuberosity [20].

Assessment of muscle strength

A priori, the study included testing the level of dominance in the functional lower extremities by kicking the ball to the target [30,31]. The lower extremity which kicked the ball was defined as the dominant leg [30,31].

The isometric and isokinetic relative peak torque for the knee flexors and extensors was measured using the Biodex System Pro 3 (Biodex Medical Systems, Shirley, NY, USA) with Biodex Advantage Software v.4.0. The participant was placed in a sitting position on a chair with a backrest. The thorax, hip, and calf were stabilized with straps [31]. The anatomical axis of rotation of the knee joint was consistent with the dynamometer axis. The knee was kept at a 90° flexion, the hip in neutral rotation and abduction, and the foot was relaxed. The Biodex was calibrated before each measurement [31].

Under isometric conditions, the same test for knee flexion (30° knee angle) and for knee extension (70° knee angle) [32,33] was repeated 3 times for each. The participant was instructed to flex/extend their knee and to exert a maximum contraction on the command "Go" of the researcher.

Under isokinetic conditions, the participant undertook the same test 5 times for the knee flexion/extension with 60°/s angular velocity and 10 times for movement with 180°/s [31,34,35]. The range of motion was 0–90° degrees for a knee joint [31,36,37]. A 5-second rest was given between each trial to avoid fatigue. A 3-minute rest was provided after testing the dominant extremity before testing the non-dominant extremity [37]. In this study, the peak torque for each muscle group (Nm/kg) and Flexors/Extensors (F/E) ratio was analyzed. A 5-minute warm-up was carried out on a cycloergometer with 65–85% maximal heart rate before all measurements of strength were made [38].

The measurements of muscle strength under isokinetic conditions were conducted by many researchers. The recommended angular velocities for assessment of hypermobile knee joints are 60°/s, 180°/s, and 240°/s [31,34,35]. The measurement protocol was recommended by the producer of Biodex System PRO3.

Assessment of muscle power and jumping ability

A 5-minute rest was provided after testing muscle strength before testing muscle power. The measurements of maximal muscle power of lower extremities and jumping ability (height of the center of mass) were carried out during Akimbo Countermovement Jump (ACMJ) on a local made PLA2–4P force platform (JBA, Poland) with MVJ software v 3.4 [39,40]. The

participant was placed in a standing position with their hands on hips. This position was adopted during all phases of the jump. The participant repeated the maximal vertical jump 3 times. The lowering of the center of mass during the jump was dependent on the individual technique of the participant [34]. A 5-second rest was provided between each jump. Relative values of maximal power (W/kg) and the height of the jump were analyzed. (cm) [34].

The entire testing (assessment of GJH, body composition, muscle flexibility, strength, and power) took 45 minutes.

Statistical analysis

The statistical analysis was performed using Statistica 13.1 (StatSoft, Poland). The descriptive statistics were calculated separately for the group with GJH and the CG. Normal distribution was assessed with the use of the Shapiro-Wilk Test. T-test and Mann-Whitney U Test were applied to assess the differences between study and control groups. The value $p = .05$ was adopted as the level of significance with a 95% confidence interval. One week before the study a preliminary test was conducted. It included 13 participants who were later included in the study group. This test allowed to verify the adopted method of measurements.

Results

Preliminary study

The preliminary study was conducted according to the same rules as the main research project. The preliminary study showed that the methods applied were well received by the participants. The measurements did not cause any fatigue, which could have a negative impact on the results. The biggest differences between the GJH and the CG was observed in the dominant lower extremity during SLR Test (76.3° vs 67.7°) and PA test (79.7° vs 64.1°) and during knee extension (3.03 vs 2.64 Nm/kg) in isometric conditions.

Participants

The participants aged 19–25 years (21.1 ± 1.6). A list of detailed characteristics is presented in Table 1. There were no significant differences between people with GJH and the CG in terms of age, weight, height, body mass index (BMI), and declared level of physical activity. All participants performed recreational aerobic physical activity.

Assessment of generalized joint hypermobility

The average result in the 9-point Beighton score in the GJH group was 6.3 ± 1.4 (Me 6.0, IQR 5–7) for women and 4.9 ± 1.1 (Me 4.5, IQR 4–6) for men. Women in the CG had an average

Table 1. Characteristics of women and men with GJH and from the CG.

	Females n = 53			Males n = 34		
	GJH	CG	p value	GJH	CG	p value
	n = 25	n = 28		n = 15	n = 19	
	Me (IQR)	Me (IQR)		Me (IQR)	Me (IQR)	
Age (years)	21.0 (20.0–23.0)	21.0 (19.0–22.0)	.68	21.0 (20.0–21.0)	21.0 (20.0–22.5)	.06
Weight (kg)	60.1 (54.8–67.9)	61.2 (54.5–70.1)	.55	80.0 (75.0–87.0)	78.0 (72.9–82.7)	.42
Height (m)	1.7 (1.6–1.7)	1.7 (1.6–1.7)	.13	1.8 (1.8–1.9)	1.8 (1.8–1.9)	.49
BMI (kg/m ²)	21.9 (19.8–24.6)	21.8 (19.7–25.8)	.72	24.6 (22.4–25.8)	24.1 (20.9–25.3)	.31
Physical activity (h/week)	3.0 (2.0–6.0)	4.0 (2.0–6.0)	.27	6.0 (5.0–7.5)	6.5 (4.0–11.5)	.24

Abbreviations: GJH—Generalized Joint Hypermobility, CG—Control Group, Me—Median, IQR—Interquartile Range.

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Table 2. The comparison of body compositions between females and males with and without generalized joint hypermobility.

	Females n = 53			Males n = 34		
	GJH	CG	p value	GJH	CG	p value
	n = 25	n = 28		n = 15	n = 19	
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)		
Fat mass (%)	28.4 (5.8)	29.2 (7.1)	.68	14.2 (3.6)	14.6 (5.7)	.82
Fat mass (kg)	17.9 (6.0)	19.8 (8.7)	.41	11.6 (3.8)	11.5 (4.7)	.98
Fat-free mass (kg)	43.6 (3.2)	45.3 (5.9)	.56	69.2 (7.0)	66.7 (6.1)	.37
Total body water (kg)	31.9 (2.4)	33.1 (4.3)	.57	50.7 (5.1)	48.8 (4.5)	.36

Abbreviations: GJH—Generalized Joint Hypermobility, CG—Control Group, SD—Standard Deviation.

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score of 1.4 ± 1.2 (Me 1.0, IQR 0–2) and men 0.5 ± 0.7 (Me 0.0, IQR 0–1). The minimum and maximum scores for women with GJH were 5 and 9, and for men 4 and 7 points, respectively. In the CG, the minimum and maximum scores for women were 0 and 4, and for men 0 and 2 points, respectively.

Assessment of body composition

The body composition analysis showed that women with GJH achieved similar scores in fat mass, fat-free mass, and total body water compared to the CG. There were no significant differences between men with GJH and from the CG in terms of body composition (Table 2).

Assessment of pelvic-hip complex muscle flexibility

Women with GJH and from the CG got similar results of the flexibility of hamstring (SLR Test and PA Test), One and Two-Joint Hip Flexors. There were also no significant differences ($p > .05$) between men with GJH and the CG in respect of muscle flexibility (Table 3).

Table 3. The comparison of muscle flexibility tests between females and males with and without generalized joint hypermobility.

	Females n = 53			Males n = 34		
	GJH	CG	p value	GJH	CG	p value
	n = 25	n = 28		n = 15	n = 19	
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)		
Lower extremity						
Dominant						
SLR (°)	65.5 (9.7)	65.8 (8.9)	.91	57.9 (12.9)	56.7 (9.7)	.81
PA (°)	67.8 (12.0)	66.0 (8.8)	.55	64.1 (13.7)	61.2 (9.2)	.81
O-JHF (°)	17.5 (8.0)	16.1 (7.5)	.46	11.1 (15.3)	4.2 (16.4)	.27
T-JHF (°)	78.4 (7.8)	78.1 (9.2)	.88	68.6 (9.7)	73.9 (9.1)	.16
Non-dominant						
SLR (°)	63.9 (9.6)	63.8 (10.5)	.96	55.6 (12.9)	57.1 (9.0)	.74
PA (°)	67.9 (10.9)	66.6 (8.4)	.61	63.6 (15.3)	58.7 (11.7)	.54
O-JHF (°)	18.9 (9.6)	16.7 (8.9)	.26	13.1 (13.8)	5.6 (14.5)	.18
T-JHF (°)	78.5 (8.1)	77.3 (8.7)	.61	65.9 (14.1)	72.5 (10.4)	.18

Abbreviations: GJH—Generalized Joint Hypermobility, CG—Control Group, SD—Standard Deviation, SLR—Straight Leg Raise test, PA—Popliteal Angle test, O-JHF—One-Joint Hip Flexors test; T-JHF—Two-Joint Hip Flexors test.

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Table 4. The comparison of peak torque under isokinetic conditions obtained by females and males with and without generalized joint hypermobility.

Peak torque/Body weight (Nm/kg)		Females n = 53			Males n = 34		
		GJH	CG	p value	GJH	CG	p value
		N = 25	n = 28		n = 15	n = 19	
Lower extremity		Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)	
Dominant							
Flexion	60°/s	0.87 (0.19)	0.90 (0.23)	.57	1.17 (0.24)	1.28 (0.32)	.39
	180°/s	0.64 (0.18)	0.63 (0.21)	.97	0.82 (0.19)	0.91 (0.23)	.31
Extension	60°/s	2.13 (0.31)	2.05 (0.43)	.53	2.55 (0.39)	2.63 (0.37)	.54
	180°/s	1.29 (0.21)	1.29 (0.33)	.46	1.55 (0.35)	1.68 (0.15)	.23
F/E (-)	60°/s	0.41 (0.07)	0.44 (0.07)	.29	0.47 (0.13)	0.48 (0.10)	.74
	180°/s	0.50 (0.12)	0.48 (0.10)	.57	0.54 (0.09)	0.57 (0.13)	.39
Non-dominant							
Flexion	60°/s	0.85 (0.17)	0.86 (0.21)	.87	1.07 (0.24)	1.21 (0.30)	.12
	180°/s	0.66 (0.15)	0.60 (0.24)	.16	0.73 (0.18)	0.93 (0.23)	.04*
Extension	60°/s	2.00 (0.28)	2.05 (0.44)	.79	2.15 (0.63)	2.59 (0.42)	.02*
	180°/s	1.23 (0.18)	1.25 (0.33)	.36	1.39 (0.37)	1.65 (0.33)	.03*
F/E (-)	60°/s	0.43 (0.09)	0.42 (0.06)	.74	0.52 (0.11)	0.47 (0.09)	.16
	180°/s	0.55 (0.11)	0.48 (0.12)	.04*	0.54 (0.07)	0.57 (0.11)	.40

Abbreviations: GJH—Generalized Joint Hypermobility, CG—Control Group, SD—Standard Deviation, F/E—Flexion/Extension ratio

* Statistically significant differences.

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Assessment of muscle strength

Under isokinetic conditions, women with GJH obtained a similar relative value of muscle peak torque during knee flexion and extension, both at 60°/s and 180°/s angular velocity compared to the CG. At 180°/s velocity, women with GJH obtained higher values F/E ratio for the non-dominant than for the dominant lower extremity, respectively 0.55 and 0.50. These values for women from the CG were equal to 0.48 for both extremities. Women from the CG received a statistically significantly lower ($p = .04$) F/E ratio at 180°/s velocity for the non-dominant lower extremity (Table 4).

Men with GJH achieved similar results during extension and flexion of the dominant lower extremity compared to the CG. For the non-dominant lower extremity, men with GJH received significantly lower ($p = .04$) flexion peak torque at 180°/s angular velocity and extension peak torque at 60°/s and 180°/s, respectively $p = .02$ and $p = .03$. Both in the studied group and the CG, men obtained the same F/E ratio during 180°/s angular velocity (Table 4).

Under isometric conditions, women with GJH obtained a similar relative peak torque during flexion and extension.

Men with GJH and from the CG received no different peak torques during extension (dominant extremity) and F/E ratio (non-dominant extremity). The remaining results of strength were similar in the study group than in the CG (Table 5).

Assessment of muscle power and jumping ability

Women with GJH obtained similar muscle power for the lower extremities and height of jump compared to the CG during the Akimbo Countermovement Jump. In the same test, men with GJH obtained a similar score for jumping ability and for muscle power in comparison with the CG (Table 6).

Table 5. The comparison of peak torque under isometric conditions obtained by females and males with and without generalized joint hypermobility.

Peak torque/Body weight (Nm/kg)	Females n = 53			Males n = 34		
	GJH	CG	p value	GJH	CG	p value
	n = 25	n = 28		n = 15	n = 19	
	Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)	
Lower extremity						
Dominant						
Flexion 30°	1.30 (0.22)	1.38 (0.24)	.25	1.85 (0.20)	1.93 (0.26)	.36
Extension 70°	2.28 (0.41)	2.32 (0.55)	.76	3.02 (0.47)	3.02 (0.48)	.98
F/E (-)	0.58 (0.08)	0.61 (0.11)	.25	0.62 (0.08)	0.65 (0.07)	.37
Non-dominant						
Flexion 30°	1.20 (0.20)	1.28 (0.22)	.19	1.64 (0.26)	1.82 (0.29)	.08
Extension 70°	2.11 (0.46)	2.32 (0.48)	.16	2.69 (0.79)	2.82 (0.38)	.09
F/E (-)	0.59 (0.13)	0.56 (0.11)	.56	0.65 (0.18)	0.65 (0.08)	.28

Abbreviations: GJH–Generalized Joint Hypermobility, CG–Control Group, SD–Standard Deviation, F/E–Flexion/Extension ratio.

<https://doi.org/10.1371/journal.pone.0236266.t005>

Discussion

The aim of the study was an evaluation of the musculoskeletal system of women and men with GJH.

Body composition

The results of the body compositions were not significantly different for people with GJH and from the CG. We were not able to find in the literature available publications containing detailed results of the body compositions for adults with GJH. Engelbert et al. [41] showed that 12-year-old boys with GJH had higher body mass and BMI compared to the CG. Sohrbeck-Nøhra's study is confirmed their results [42].

Pelvic-hip complex muscle flexibility

Women and men with GJH obtained similar values of hamstring flexibility (SLR and PA tests) and for One- and Two-Joint Hip Flexors (O-JHF, T-JHF) compared to the control groups. Czaprowski et al. [20] did not notice any significant differences between girls and boys aged 10–13 with GJH in comparison with the control groups. Their study included the modified Finger-To-Floor test (FTF) and the Lateral Trunk Flexion test (LTF). Czaprowski et al. [20] claimed that the clinical examination of the pelvic-hip complex muscle and trunk flexibility was insufficient in diagnosing GJH in children and the Beighton score should be considered a standard element of physiotherapeutic examination of the musculoskeletal system.

Table 6. The comparison of maximal muscle power and jumping ability obtained by females and males with and without generalized joint hypermobility.

	Females n = 53			Males n = 34		
	GJH	CG	p value	GJH	CG	p value
	n = 25	n = 28		N = 15	n = 19	
	Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)	
Maximal Power (W/kg)	16.6 (3.8)	17.1 (4.2)	.66	23.1 (3.6)	22.8 (4.7)	.85
Height of jump (cm)	25.3 (2.9)	25.9 (3.9)	.52	34.3 (5.8)	35.3 (5.4)	.64

Abbreviations: GJH–Generalized Joint Hypermobility, CG–Control Group, SD–Standard Deviation.

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Muscle strength

The measurements of muscle strength in people with GJH have been the participant of much research [17,34,43,44,45], but the results presented do not allow a clear determination of the effect of joint hypermobility on the level of this feature. According to Jindal et al. [45], this is due to the lack of consideration in the interpretation of muscle strength measurements e.g. human race population, sex, age, functional dominance of extremities, or a variety of muscle groups to be measured [45].

Under isokinetic conditions, women with GJH obtained similar results of peak torque compared to the CG. Moreover, women from the CG received significantly lower F/E ratio (non-dominant extremity) compared to the remaining groups. This was due to the achievement of low values of peak torque during the extension of the knee joint. In men, all results for peak torque were similar to the CG. Only the value of strength during flexion at 180°/s and extension at 60°/s and 180°/s angular velocity was significantly lower for men with GJH. Liaghat et al. [46] claimed that higher velocities such as 180°/s have been defined as corresponding to muscle power (the ability to generate as much force and as fast as possible) and under 120°/s as corresponding to strength (the amount of force muscles can exert against an external load) [46]. Our study showed that it was possible that men with GJH had greater problems with muscle power than with muscle strength. However, the results of Akimbo Countermovement Jump did not confirm this tendency. These results were unlike that found by Liaghat et al. [46], who observed lower peak torque at 60°/s angular velocity, representing strength deficit in young competitive swimmers with GJH.

Juul-Kristensen et al. [34] applied a similar methodology in the examination of people with GJH. They used the Kinetic Communicator. They did not observe many differences in the relative strength of participants with GJH compared to the CG. However, in the case of girls and women with GJH, a significantly lower peak torque for the extension of the knee joint under isokinetic conditions was observed [34]. These results are a partial confirmation of our study, where men with GJH have seen a decrease in strength during knee flexion and extension for non-dominant lower extremity.

This study showed that women and men with GJH had a tendency to lower value peak torque under isometric conditions compared to the CG, but the differences were not statistically significant. Similar results were presented by Jensen et al. [43] and Mebes et al. [47]. Engelbert et al. [17] and Junge et al. [44] did not observe any differences in strength in children with GJH under isometric conditions compared to the CG. Juul-Kristensen et al. [34] and Massy-Westropp and Toubi [48] did not find significant differences in hand-grip between people with joint hypermobility and healthy participants. Yazgan and Duymaz [49] reported a lower strength for hand-grip in women with GJH than in the CG, but there were no significant differences in muscle strength in the lower extremity.

In this study participants with GJH had a tendency to manifest lower peak torque, especially under isometric conditions. The International Classification of Functioning, Disability and Health–ICF confirms the existence of lower muscle strength under isokinetic and isometric conditions [50], which occurs in Benign Joint Hypermobility Syndrome (BJHS) [35,51].

Jindal et al. [45] carried out their study using the Primus RS Isokinetic Dynamometer. They observed that men with GJH obtained significantly lower strength during elbow extension and knee extension (dominant extremity) compared to the CG. There were no differences between women with GJH and from CG [45]. This is a confirmation of our results, despite another angle of the knee joint during measurements (90° in Jindal's et al. and 70° in our study).

Jensen et al. [43] showed that children and adults with GJH obtained similar results of muscle strength during knee extension and flexion and for F/E ratio compared to the control

groups. In adults with GJH, the value of peak torque during knee extension was higher than in this study. However, during flexion, it was lower. This caused a distinct difference in the F/E ratio, which in Jensen et al. [43] was 0.38, and 0.6 (-) in our study, respectively. The differences could be caused by the participant groups' different age profiles and the knee angle of equal to 100° [43]. According to Jensen et al. [43], low muscle strength during flexion and high during extension may indicate that there is a compensatory strategy to increase the stability of the knee joint.

Scheper et al. [16] claimed that the reduction of muscle strength is related to joint instability, worse proprioception, and pain. One of the criteria for differentiating people with GJH from people with Hypermobility Syndrome (HS) or Benign Hypermobility Syndrome (BHS) is back pain and pain in the peripheral joints [4,11,13]. In literature, there is evidence of a significant reduction in muscle strength in people with joint pain [34,35,51]. It should then be assumed as the inclusion and exclusion criteria from the study.

Sahin et al. [35] in researching the BIODEX System PRO 3 observed a reduction of peak torque during knee extension. They reported a decreased level of physical activity caused by pain [35] as a reason for this. According to Fatoye et al. [51], children with Joint Hypermobility Syndrome (JHS) manifested a reduction of peak torque during knee extension and flexion under isokinetic conditions [51]. Scheper et al. [52] claimed that people with GJH can modify their behavior, avoid dynamic activities, and refrain from erratic movement in order to prevent musculoskeletal problems. Remvig et al. [53] were unable to demonstrate any increased prevalence of joint pain, reduced motor competence, or reduced physical activity in school children with GJH or BJHS. But Sohrbeck-Nøhr et al. [42] claimed that it is possible to link between GJH with joint pain in the adolescent population. Chronic pain is common in the BJHS [4,8].

Muscle power and jumping ability

The Akimbo Countermovement Jump (ACMJ) is a reliable method for the measurement of muscle power in lower extremities. It is used in the assessment of top-class athletes [54].

In this study, women and men with GJH achieved similar results for jumping ability (height of jump) and relative power compared to the control groups. Juul-Kristensen et al. [34] have not observed any differences between adults with GJH and from the CG during ACMJ on AMTI platform but children with GJH were found to have significantly higher values of jumping ability in comparison with the CG. Remvig et al. [53] used the Abalakov Test to assess the height of the jump. In children with GJH, there was no significant change in the jumping ability measured using the Beighton score [53]. The Sohrbeck-Nøhr et al. [42] study did not show any significant differences in children achieving 4, 5, and 6 points in the Beighton score.

Limitations and clinical relevance

The study included measurements of body composition and muscle flexibility as factors affecting muscle strength and muscle power. The limitation of this study was the fact that the studies did not take into account the measurements of upper extremities and trunk muscle strength. The measurements did not include the assessment of all muscles surrounding the joints evaluated in the Beighton score. The aim of physiotherapy in people with GJH is the elimination of postural disorders and impaired proprioception or coordination [10–14]. The authors recognized that the function of the upper extremities had little impact on the occurrence of these disorders.

The results of this study did not show many differences in muscle strength between the GJH group and the CG. A decreased muscle strength in people with GJH could suggest that an increase in the level of this feature should be the therapeutic goal. That there are no differences

does not exclude the efficacy of strength training in increasing levels of muscle strength in order to improve the function of the musculoskeletal system in people with GJH beyond that found in healthy subjects. This issue would require further research to examine the impact of strength training on body posture and the shaping of proprioception or coordination.

Conclusions

1. The comprehensive diagnosis, which included the assessment of body components, muscle flexibility, muscle strength, power, and jumping ability did not show many differences between young adults with Generalized Joint Hypermobility and healthy people.
2. Under isometric conditions, the peak torque does not differ in young adults with Generalized Joint Hypermobility compared to the CG.
3. Healthy men obtained a higher peak torque for the non-dominant extremity under isokinetic conditions compared to young adults with Generalized Joint Hypermobility.

Supporting information

S1 Table. Characteristics of women and men with GJH and from the CG.

(DOC)

S2 Table. The comparison of body compositions between females and males with and without Generalized Joint Hypermobility.

(DOC)

S3 Table. The comparison of muscle flexibility tests between females and males with and without Generalized Joint Hypermobility.

(DOC)

S4 Table. The comparison of peak torque under isokinetic conditions obtained by females and males with and without Generalized Joint Hypermobility.

(DOC)

S5 Table. The comparison of peak torque under isometric conditions obtained by females and males with and without Generalized Joint Hypermobility.

(DOC)

S6 Table. The comparison of maximal muscle power and jumping ability obtained by females and males with and without Generalized Joint Hypermobility.

(DOC)

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