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Mechanical Properties of Muscles and Tendons in Asymptomatic Individuals with Generalized Joint Hypermobility

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SUMMARY

Background. The purpose of the present study was to investigate changes in mechanical properties of muscles and tendons in asymptomatic individuals with generalized joint hypermobility (GJH).

Methods. This cross-sectional study was conducted in 126 participants aged 19-40 years. The Beighton score was used to determine whether the participants had GJH. An experienced physiotherapist screened all participants using the Beighton score to inquire about the presence of GJH. At the end of the clinical evaluations, 36 asymptomatic participants with GJH (age, 24.6 ± 6.1 years) and 34 age- and sex-matched controls (age, 24.6 ± 6.8 years) were included in the present study. The oscillation frequency (indicator of tone), dynamic stiffness (indicator of stiffness), and logarithmic decrement (related to elasticity) of the medial and lateral gastrocnemius, biceps brachii, and brachioradialis muscles, and the Achilles and patellar tendons were measured with a portable myotonometer (MyotonPRO, Myoton AS, Tallinn, Estonia).

Results. The oscillation frequency, dynamic stiffness, and logarithmic decrement of the biceps brachii, brachioradialis, and medial and lateral gastrocnemius muscles were similar in GJH and control groups ($p > 0.05$). In addition, there was no significant difference between groups in terms of the oscillation frequency, dynamic stiffness, and logarithmic decrement of the Achilles and patellar tendons ($p > 0.05$).

Conclusions. The elasticity, stiffness, and/or tone of the biceps brachii, brachioradialis, and medial and lateral gastrocnemius muscles were similar in individuals with and without GJH. The results obtained suggest that the mechanical properties of muscles and tendons are not associated with GJH.

KEY WORDS

Generalized joint hypermobility; muscle; tendon; stiffness; elasticity.

BACKGROUND

Generalized joint hypermobility (GJH) describes a condition involving joints that actively or passively demonstrate excessive movement beyond the expected or normal physiological range (1). The prevalence of the GJH is reported to vary between 12.5% and 39% in the general population (2, 3). GJH is associated with many factors such as sex, age, and race. It is well known that females or younger age groups have a higher hypermobility compared to males or older age groups (4). On the other hand, GJH is related to musculoskeletal pathological conditions such as back pain, sprains, dislocations, or balance problems (2). There are various explanations about high prevalence of musculoskeletal pathological conditions in individuals with GJH. It is suggested that higher tissue elasticity may cause a decrease in passive or active joint stability (5). The decrease in joint stability may alter force production and transmission related to musculotendinous structures (6, 7). These changes in joint stability or transmission related to musculotendinous structures may result in an overload on the joint or related structures in the long run.

There are some factors associated with joint hypermobility such as hormonal imbalance, genes encoding collagen, or environmental factors (8-10). These factors have the potential to cause changes in mechanical properties of soft tissues, such as muscles and tendons (11-13). The changes in mechanical properties of soft tissues may be a factor in excessive movements involving joints in individuals with GJH. Mechanical properties such as tone, stiffness, and elasticity of muscles and tendons are important components of joint stability or joint controls (14, 15). Changes in mechanical properties of muscles and tendons may be an important factor causing the joint excessive movement in individuals with GJH. There exist very few studies presenting the changes in mechanical properties of muscle and tendon structures in symptomatic patients with the Ehlers-Danlos syndrome (16-18). Mechanical properties of muscles and tendons would be different in asymptomatic individuals with GJH. It is well known that orthopaedic conditions or orthopaedic conditions related pain may change the mechanical properties of muscles and tendons (19-21). In addition, the stiffness of muscles, tendons, or musculotendinous structures has been investigated only in these studies; however, other parameters such as tone or elasticity of muscles and tendons has not been investigated. Identifying a possible change in mechanical properties of muscles and tendons may help practitioners better understand the pathomechanics of increased prevalence of musculoskeletal pathological conditions in asymptomatic individuals with GJH.

There are several methods for the measurement of muscle and/or tendon stiffness, such as myotonometry, elastography, shear-wave elastography, and magnetic resonance. Myotonometry has some advantages over magnetic resonance elastography and shear-wave elastography. For example, the myotonometer is a portable device that allows measurements in different environments. On the other hand, it is relatively low-cost compared to magnetic resonance and/or ultrasonography devices. Measurement made with myotonometry is easily learned and it is simple to apply compared to magnetic resonance elastography and shear-wave elastography. In addition, it has been reported that the reliability and validity of myotonometry are similar to those of magnetic resonance and shear wave elastography (22-25). In addition, while magnetic resonance and shear-wave elastography allow only stiffness measurements in soft tissue, besides measuring stiffness, the myotonometer can also measure other mechanical properties such as tone and elasticity.

The purpose of the present study was to investigate the change in the elasticity, stiffness, and/or tone of muscles and tendons in asymptomatic individuals with GJH. It was hypothesized that (1) muscle and tendon stiffness would be lower in asymptomatic individuals with GJH, and (2) muscle and tendon elasticity would be higher in individuals with GJH compared to controls.

METHODS

Ethics permission

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with 1964 Helsinki declaration and its later amendments or comparable ethical standards. To conduct the study, permission was obtained from the ethics committee of Toros University (Protocol no: 2021-5/58). Prior to the study, oral and written informed consents were provided by all participants.

Sample size calculation

Prior to the study, a power analysis was conducted using a statistical analysis program (IBM Corporation, SPSS Sample Power 3.0 Software Armonk, NY, USA) to identify the minimum required sample size. The minimum required sample size was calculated to be at least 27 participants for each group for the desired power (β) of 80% with an assumed alpha level (α) of 0.05 to detect a minimum clinical difference of 40 N/m muscle stiffness when the average muscle stiffness value in the control group is 257 N/m with a standard deviation of 53 N/m (22).

Individuals

This cross-sectional study was conducted in 126 participants aged 19-40 years, who were students/staff of Alanya Alaaddin Keykubat University and Toros University. The Beighton score, which was reported as a valid and reliable tool for assessing GJH (26, 27), was used to determine whether the participants had GJH. The Beighton score consists of 5 items as follows: 1) the fifth metacarpophalangeal joint passive dorsiflexion score is positive if ≥ 90° (bilateral testing), 2) the thump opposition score is positive if the thump reaches the forearm volar aspect (bilateral testing), 3) the elbow passive hyperextension score is positive if ≥ 10° (bilateral testing), 4) the score of the knee passive hyperextension is positive if ≥ 10° (bilateral testing), and 5) the spinal hypermobility score is positive if the hand palms rest easily on the floor with straight knees (26, 27). The Beighton score ranges from 0 to 9. A Beighton score of ≥ 5/9 indicates the presence of GJH for adults up to age of 50 years (28). An experienced physiotherapist screened all participants using the Beighton score to inquire about the presence of GJH. At the end of the clinical evaluations, 36 asymptomatic participants with GJH (age, 24.6 ± 6.1 years) and 34 age- and sex-matched controls (age, 24.6 ± 6.8 years) were included in the present study (**figure 1**). Individuals were excluded from the study if they reported any of the following conditions: 1) having a history of a major trauma, lower extremity fracture or surgery, 2) having an upper or lower orthopedic disorder, such as tendinitis, muscle strain/sprain, or ligaments injury, 3) having multiple joint pain for longer than 3 months, 4) having a systemic disease, such as diabetes mellitus, 5) having a neurological or cardiopulmonary disorders, or rheumatic diseases, 6) having a body mass index more than 30 kg/m², and 7) having performed any strenuous exercises within 48 h prior to measurements.

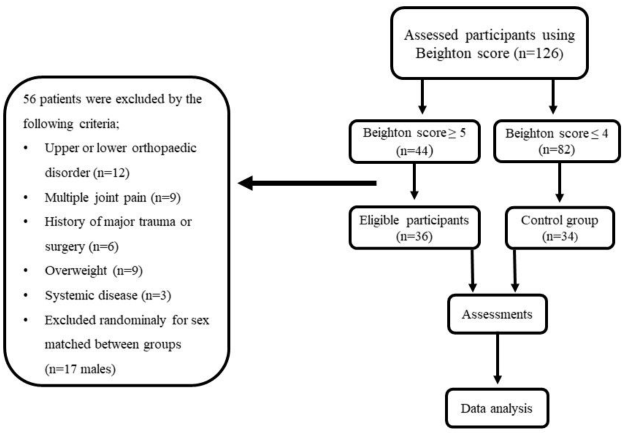

Figure 1. Sample selection fluxogram.

Mechanical properties measurements

Mechanical properties of the medial and lateral gastrocnemius, biceps brachii, and brachioradialis muscles, and the Achilles and patellar tendons were measured with a portable myotonometer (MyotonPRO, Myoton AS, Tallinn, Estonia) (**figure 2**). The MyotonPRO has been reported as a reliable and valid device for measuring mechanical properties of muscles and tendons (22, 23, 29). The MyotonPRO applies a mechanical impulse with a constant mechanical force (up to 0.6 N) and short duration (15 milliseconds) to the target structure. After this mechanical impulse, measuring the mechanical oscillations in the target structure by the device provides the following data: 1) logarithmic decrement, 2) dynamic stiffness (N/m), and 3) oscillation frequency (Hz). Logarithmic decrement shows the elasticity of the target soft tissue. Dynamic stiffness (N/m) gives important information about the resistance capacity of the soft tissue against an external force. Oscillation frequency (Hz) provides information about the tone of the muscle in passive or resting state.

Figure 2. MyotonPRO was used for measurements of the mechanical properties of the selected muscles.

Mechanical properties of the selected tissues were measured by a physiotherapist with a 3-year experience with myotonometric measurements, and who was blinded to the groups. The dominant hand of the individuals was determined by questioning about the hand they used while writing (30), and the dominant leg of the individuals was determined by questioning about the leg they used while kicking the ball (31). Similar to previous studies (22, 32), the mechanical properties of the Achilles tendon were measured on the point 3 cm above the calcaneal tuberosity. Based on previous studies (22, 32), the measurements of the medial and lateral gastrocnemius muscle were performed at a point 70% off of the lower leg length in line with the popliteal crease to the lateral malleolus. The Achilles tendon and medial and lateral gastrocnemius measurements were performed while the individuals were in prone position, the knees at full extension, and the ankle at neutral position. The patellar tendon measurements were performed at midpoint between the inferior pole of the patella and tuberositas tibiae while the individuals were sitting with their legs over the edge of the bed and knees flexed to 90 degrees (33). For the measurements of the biceps brachii muscle, the participants lay in supine position with the wrists supinated, the elbows at 15° flexion, and the shoulder at neutral position and externally rotated. The measurements of the biceps brachii were performed at midpoint between the acromion and cubital fossa (34). The measurements of the brachioradialis were performed at one-thirds distance from the styloid process to the lateral supracondylar ridge, while the participants lay supine with forearm pronated and elbow extended (35) (**figure 3**). Each test was performed three times, and the average of the three measurements was noted.

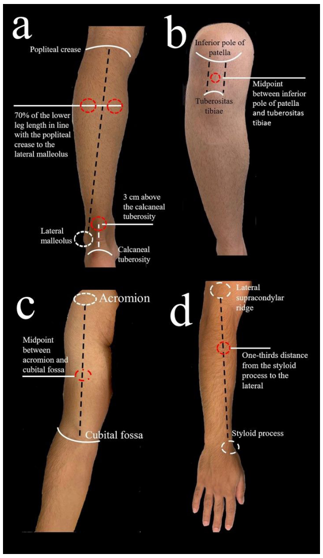

Figure 3. Locations of the myotonometric measurement: (**a**) Achilles tendon, medial and lateral gastrocnemius muscle, (**b**) patellar tendon, (**c**) biceps brachii muscle, (**d**) brachioradialis muscle.

Statistical analyses

Statistical analyses were performed using a statistics software program (SPSS for Windows version 22, IBM Corporation, Armonk, NY, USA). Analytical (Kolmogorov–Smirnov/Shapiro–Wilk's test) and visual methods (histograms, probability plots) were performed to decide whether the parameters were normally distributed. Mean and standard deviation are used to present the normally distributed variables. Student's t-test was used to compare the parameters between the GJH and control groups. A p-value of less than 0.05 was considered to show a statistically significant result.

RESULTS

Both groups had similar age ($p = 0.940$), height ($p = 0.437$), weight ($p = 0.290$), and body mass index ($p = 0.700$) (**table I**). The oscillation frequency, dynamic stiffness, and logarithmic decrement of the biceps brachii, brachioradialis, and medial and lateral gastrocnemius muscles were similar in both GJH and control groups ($p > 0.05$). In addition, there was no significant difference between groups in terms of the oscillation frequency, dynamic stiffness, and logarithmic decrement of the Achilles and patellar tendons ($p > 0.05$) (**table II**).

DISCUSSION

The purpose of the present study was to investigate changes in mechanical properties of muscles and tendons in indi-

Table I. Demographic data of GJH and control groups.

Parameter	Control group (n = 34)	GJH group (n = 36)	P value
Age (year)	24.6 ± 6.8	24.6 ± 6.1	0.940
Height (m)	1.64 ± 0.08	1.66 ± 0.08	0.437
Weight (kg)	58.4 ± 12.2	61.0 ± 15.5	0.290
BMI (kg/m^2)	21.5 ± 3.2	21.9 ± 4.3	0.700
Beighton score	1.6 ± 1.0	6.1 ± 1.3	**< 0.001**
Sex			
Male, n (%)	6 (17.6 %)	6 (16.6 %)	
Female, n (%)	28 (82.4 %)	30 (83. 4 %)	
Dominant hand			
Right, n (%)	32 (94.1 %)	35 (97.2 %)	
Left, n (%)	2 (5.9 %)	1 (2.8 %)	
Dominant limb			
Right, n (%)	31 (91.2 %)	35 (97.2 %)	
Left, n (%)	3 (8.8 %)	1 (2.8 %)	

*$p < 0.05$. Data are presented as mean ± standard deviation.

Table II. Comparisons of the mechanical properties of the assessed tissues between GJH and control groups.

Parameters	Control group (n = 34)	GJH group (n = 36)	P value
Medial gastrocnemius muscle			
Frequency (Hz)	15.0 ± 1.8	14.7 ± 1.6	0.462
Stiffness (N/m)	261.7 ± 44.4	249.1 ± 43.4	0.236
Logarithmic decrement	1.0 ± 0.1	1.0 ± 0.1	0.763
Lateral gastrocnemius muscle			
Frequency (Hz)	15.2 ± 1.9	14.9 ± 2.1	0.486
Stiffness (N/m)	271.5 ± 55.2	262.49.0	0.386
Logarithmic decrement	1.0 ± 0.1	1.0 ± 0.2	0.661
Biceps brachii muscle			
Frequency (Hz)	13.4 ± 1.0	13.1 ± 0.9	0.177
Stiffness (N/m)	199.8 ± 21.1	200.7 ± 21.3	0.851
Logarithmic decrement	1.2 ± 0.2	1.2 ± 0.2	0.977
Brachioradialis muscle			
Frequency (Hz)	15.5 ± 1.0	15.2 ± 0.8	0.100
Stiffness (N/m)	252.1 ± 26.0	244.1 ± 19.0	0.143
Logarithmic decrement	0.9 ± 0.1	1.0 ± 0.1	0.509
Achilles tendon			
Frequency (Hz)	30.8 ± 2.2	30.9 ± 2.0	0.939
Stiffness (N/m)	783.4 ± 66.7	774.7 ± 69.8	0.596
Logarithmic decrement	0.8 ± 0.1	0.8 ± 0.1	0.311
Patellar tendon			
Frequency (Hz)	22.0 ± 3.2	21.8 ± 3.5	0.888
Stiffness (N/m)	623.1 ± 143.7	640.5 ± 136.4	0.606
Logarithmic decrement	0.9 ± 0.1	0.9 ± 0.2	0.941

Data are presented as mean ± standard deviation.

viduals with GJH. It was hypothesized that the elasticity of muscles and tendons would be higher, and their stiffness would be lower in individuals with GJH compared to controls. The hypothesis was based on the idea that mutation in the genes encoding collagen and deficiency or hormonal imbalance in individuals with hypermobility-related disorders (9, 10) may cause a collagen deficiency in musculoskeletal structures, and it may cause a change in mechanical properties of muscles and tendons. Changes in mechanical properties of muscles and tendons may be a factor for the excessive movements involved in joints in individuals with GJH, because mechanical properties of muscles and tendons are important components of joint stability or joint controls (14, 15). In addition, potential changes in mechanical properties of muscles and tendons may be related to the increase in the prevalence of musculoskeletal pathological conditions in individuals with GJH (5-7). Different from the hypothesis, it was found that elasticity, stiffness, and tone of the Achilles tendon, patellar tendon, biceps brachii muscle, brachioradialis muscle, and the medial and lateral gastrocnemius muscle were similar in individuals with and without GJH. The results obtained show that the mechanical properties of muscles and tendons were not associated with GJH. There are some studies investigating the mechanical properties of muscles or tendons. Similar to the results obtained, Magnusson *et al.* (36) reported that passive properties of the muscle-tendon unit were similar in women with benign joint hypermobility syndrome and controls. On the other hand, Alsiri *et al.* (16) conducted a study to assess the changes in mechanical properties of muscles and tendons in hypermobility spectrum disorders by strain elastography. They reported that the elasticity of the brachioradialis muscle, Achilles, and patellar tendon was lower in hypermobility spectrum disorders; however, the elasticity of the deltoid, biceps brachia, rectus femoris, and gastrocnemius muscles was similar in individuals with hypermobility spectrum disorders and controls (16). Different from our results, Rombaut *et al.* (17) investigated the passive properties of the plantar flexors muscle-tendon tissue in patients with the hypermobility type of Ehlers-Danlos syndrome by measuring the passive muscle tension with an isokinetic dynamometer. They found that patients with the hypermobility type of Ehlers-Danlos syndrome had a lower passive muscle tension in plantar flexors and Achilles tendon stiffness (17). Moreover, Nielsen *et al*. (18) investigated patellar tendon stiffness in patients with Ehlers-Danlos syndrome by force and ultrasonographic measurements during a ramped isometric knee extension. They indicated that patellar tendon stiffness was lower in patients with Ehlers-Danlos syndrome compared to healthy controls (18). There are some potential causes related to the differences in results reported in the literature. It seen that different techniques, such as measuring passive resistive torque (17, 18, 36), or equipment, such as strain elastography, have been used to measure the mechanical properties of muscles and tendons. Using different techniques or equipment may have caused differences in the results. For example, almost all of the studies in the literature calculated stiffness by measuring passive resistive torque and tendon/muscle-tendon tissue elongation. In this technique, tendon/muscle-tendon tissue elongation is measured during maximal isometric contraction and tension of the tendon/muscle-tendon tissue (17, 18, 36). Contrary to these studies, the passive mechanical properties of the assessed tissues were carried out in full rest position using a myotonometer. On the other hand, studies reporting a change in mechanical properties of muscles and tendons have been conducted with symptomatic participants with Ehlers-Danlos syndrome or hypermobility spectrum disorders (16, 17). The reported changes in the mechanical properties of muscles and tendons in these studies (16, 17) may be related to orthopaedic disorders or chronic multiple-joint pain of the study participants. It is well known that orthopaedic conditions or orthopaedic conditions related to pain may change the mechanical properties of muscles and tendons (19-21).

The study has some limitation. First, the study was conducted with young participants. Mechanical properties of muscles and/or tendons would be different in middle aged or geriatric individuals with GJH. Second, the mechanical properties of muscles and tendons were only measured in the passive state. They may be different in tension or loading conditions in individuals with GJH. Further studies are needed to investigate the mechanical properties of muscles and tendons in tension or loading conditions in individuals with GJH. Lastly, the assessed muscles are global movers of the related joint. The mechanical properties of the stabiliser muscles may be different in individuals with GJH.

CONCLUSIONS

It was found that the elasticity, stiffness, and/or tone of the biceps brachii, brachioradialis, and medial and lateral gastrocnemius muscles were similar in individuals with and without GJH. The results obtained show that the mechanical properties of muscles and tendons are not associated with GJH. The results also suggest that mechanical properties of muscles and tendons are not associated with the excessive movements involving joints in individuals with GJH.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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